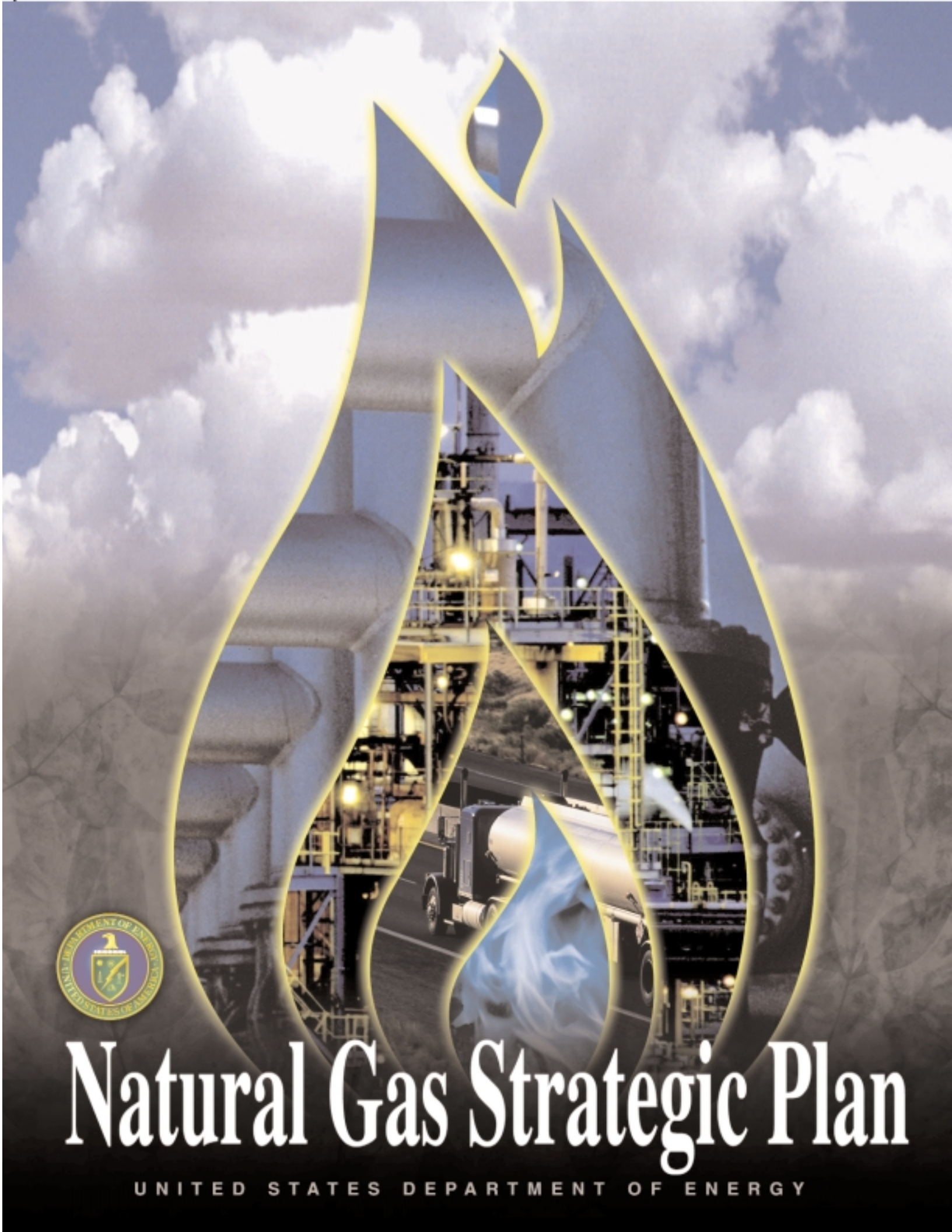
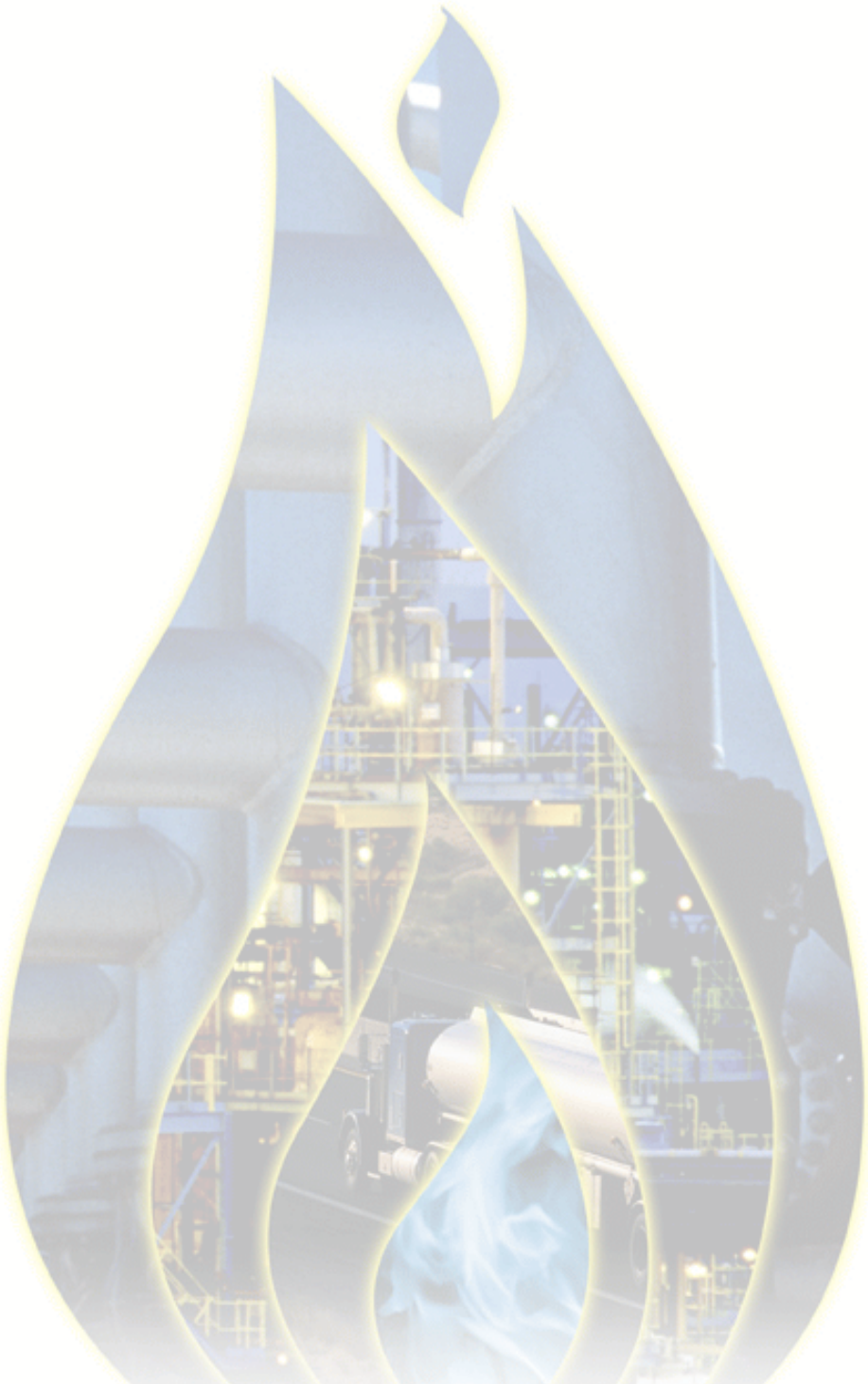


# Natural Gas Strategic Plan

UNITED STATES DEPARTMENT OF ENERGY



# Natural Gas Strategic Plan

UNITED STATES DEPARTMENT OF ENERGY

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# Foreword

Because of deregulation and restructuring in the electric power industry, as well as global climate change considerations, the demand for natural gas is anticipated to increase dramatically from 22 Tcf to 35 Tcf by 2020. In May 1998 the Secretary of Energy requested that the National Petroleum Council (NPC)[1] update their 1992 study, *Potential of Natural Gas in the United States*.

The resulting NPC study[2] had, as its first recommendation, "**Government and industry must take a leadership position in establishing—at the highest level—a strategy for natural gas in the nation's energy portfolio. An Interagency Work Group on Natural Gas should be established to work with industry and other stakeholders to formulate the strategy and resolve issues**."[3]

The *Natural Gas Strategic Plan* reflects the United States Department of Energy's (DOE) response to the NPC recommendation. This plan is intended as input to the White House Interagency Working Group on Natural Gas, which was also established in response to the NPC recommendation. The basis for this strategic plan is the DOE *Comprehensive National Energy Strategy* (CNES)[4] and supporting *Energy Resources Portfolio,*[5] together with recommendations by the NPC, the President's Committee of Advisors on Science and Technology (PCAST), the Laboratory Energy Research and Development Working Group (LERDWG), State and local governments, universities, trade

associations, and members of industry. Within DOE, the key organizations involved in the development of the plan were the Office of Fossil Energy (FE), the Office of Energy Efficiency and Renewable Energy (EERE), the Office of Policy, the Office of Science, the Energy Information Administration (EIA), and the National Energy Technology Laboratory's Strategic Center for Natural Gas (SCNG). Working jointly with the DOE's program offices and laboratories, the SCNG will support development of policies and technologies to improve methods of finding, producing, delivering, and using natural gas.

The DOE's current and planned natural gas programs will support the overall goals of enhancing energy security, energy reliability, energy affordability, and clean energy while contributing to economic growth. Specific strategies under the *Natural Gas Strategic Plan* are presented in the context of the DOE *Energy Resources Portfolio* goals and objectives,[6] along with an additional goal pertaining to energy information.

This document does not prioritize the strategies in terms of budgets or other figures-of-merit; nor does it address details of management and coordination among Federal agencies. It does provide a strategy that is comprehensive in outlook, and one that addresses all the major needs consistent with the government role. The appendixes supply supporting information on DOE programs designed to address the goals, objectives, and strategies.

# Executive Summary

***Vision:*** *By 2020 the U.S. public is enjoying greater environmental and economic benefits from the use of natural gas.*

Clean, affordable, reliable, secure energy is vital to the health and well being of Americans and the U.S. economy. Natural gas—domestically abundant, clean burning, and affordable—will be the fuel of choice in meeting the expanding energy demand.

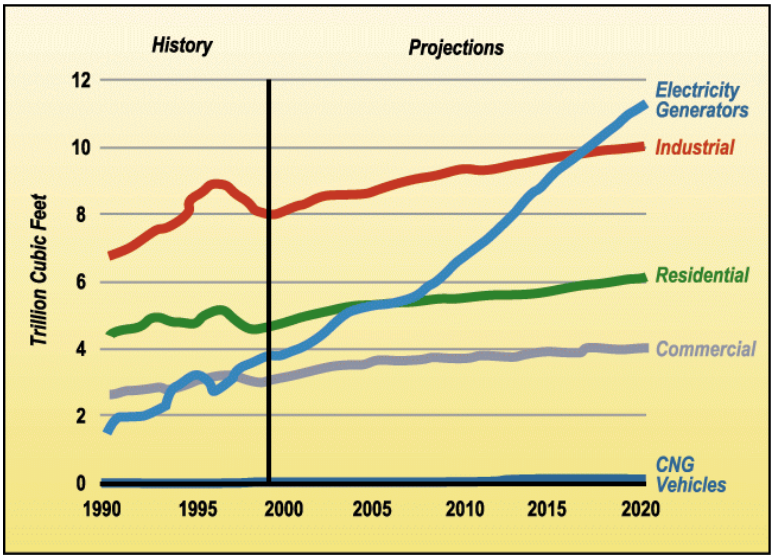
Over the next 20 years, natural gas will play an increasingly significant role in meeting U.S. energy needs cleanly, affordably, and reliably. Natural gas is the primary fuel used for home heating and is the fuel of choice for 70 percent of new home construction.[7] It is, also, the primary fuel used to provide process heat for U.S. manufacturing and process industries. Even more dramatically, it is estimated that 90 percent of planned new power plants may be gas fueled.[8]

However, recent price volatility has led to concerns about the sustainable production and delivery of this important fuel. A coherent national strategy is needed to integrate Federal and State policy, regulatory, technology, and incentive programs to overcome these concerns and provide for a secure energy future. This Department of Energy (DOE) *Natural Gas Strategic Plan* will initiate the development of such a national strategy. It is recommended that this plan be a basis for the ongoing activities of the Interagency Working Group on Natural Gas.

## Market Outlook

Over the next 20 years, natural gas consumption is expected **to grow from 22 trillion cubic feet (Tcf) to almost 35 Tcf**.[9] Consumption will increase in every sector. The increased demand for electricity generation will be the largest driver; consumption in this sector is expected to triple to **more than 11 Tcf**[10] (see **Figure ES-1**). The domestic supply is sufficient to meet growing demand. However, to meet the demand, we must be ready to:

- Collaborate with Federal, State, tribal departments and agencies and with industry to produce integrated policies.
- Develop new technologies rapidly.
- Streamline regulatory processes.
- Re-examine portions of the resource base that are not readily available for development due to current restrictions.
- Expand transmission and delivery systems significantly by an estimated 38,000 miles of new transmission lines and 255,000 miles of new distribution lines.[11]




Source: DOE/EIA, *Annual Energy Outlook 2001 with Projections to 2020*, December 2000, p. 84.

**Figure ES-1. Natural Gas Use is Projected to Increase Most Dramatically for Electricity Generation**

## Strategy

The proposed natural gas strategy addresses the challenges to realizing the full benefits of natural gas today and in the foreseeable future. Fundamental and complex changes in the energy marketplace and the need to increase the natural gas supply will involve many organizations, both governmental and industrial. The overarching strategy is to **integrate policy, regulation, technology, and incentives**.

Because its primary mission is energy related, the DOE is the primary Federal department providing policy recommendations and technical assistance to the White House Interagency Working Group on Natural Gas. The recently established National Energy Technology Laboratory's Strategic Center for Natural Gas (NETL/SCNG) would provide a key resource for coordinating, developing, and analyzing interagency working group proposals.

In analyzing energy challenges, the DOE identified three challenges for energy policy makers:[12]

- Maintaining America's energy security in global markets.
- Harnessing the forces of competition in restructured energy markets.
- Mitigating the environmental impact of energy use.

The goals, objectives, and strategies in the *Natural Gas Strategic Plan* are consistent with the high-level policy principles, goals, and challenges presented in the *Comprehensive National Energy Strategy*[13] and *Powering the New Economy*,[14] as well as the program implementation of the DOE's *Energy Resources Portfolio*.[15]

**Figure ES-2** shows these goals and objectives. The fourth goal is not listed in the *Comprehensive National Energy Strategy*. This goal, to provide energy information for the use of Government agencies, is recommended as an enabler of the collaboration among agencies and industry.

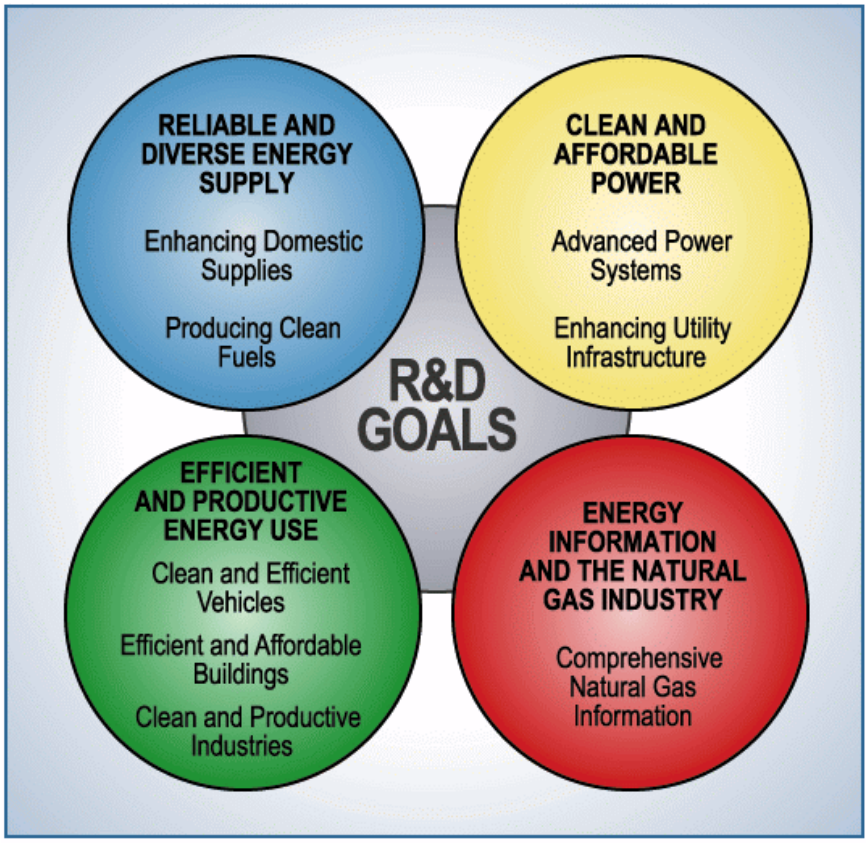



**Figure ES-2. R&D Goals and Objectives**

The **Strategy** section of this document provides a definitive link between policy, principles, goals, and challenges and the technology investment strategies needed to mitigate these challenges and meet the goals. Tables ES-1 through ES-4 summarize these technology investment strategies.

## Reliable and Diverse Energy Supply

The Federal Government should provide sufficient opportunity and incentive to increase natural gas supplies, as well as promote the development of advanced technologies aimed at increasing the amount of gas that is technically recoverable, at reducing exploration and production expenses, and at reducing environmental impact. A review of policies regulating access to Federal lands, financial incentives, environmental policy and technology policy and investment should also be initiated. **Table ES-1 shows the objectives and strategies associated with this goal.**

**Table ES-1. Reliable and Diverse Energy Supply**

| R&D Objectives | Strategies |
|---|---|
| Enhancing Domestic Supplies | • Accelerate technology development for exploration and production of non-conventional resources, deep resources, deep off-shore Gulf of Mexico resources, and methane hydrates.<br>• Explore financial incentives for production of non-conventional resources.<br>• Conduct R&D with industry, universities, and national laboratories to advance technology development aimed at maximizing the productivity of each well and reducing the impact of production needed to access gas on Federal lands.<br>• Stimulate gas-to-liquids technology development to bring stranded gas to market.<br>• Advance technology development for efficient and environmentally benign gas processing technologies to bring low quality gas to market. |
| Producing Clean Fuels | • Participate in the coordinated management, planning and implementation of the Department's Ultra-clean Transportation Fuels Program and leverage the Fuels Program activities to produce the data and technology needed to develop and commercialize fully integrated natural gas engines and emissions controls.<br>• Conduct outreach efforts to increase consumer acceptance of alternative fueled vehicles.<br>• Develop and implement the technologies needed to optimize the fuels product slate to meet national and regional demands. |

## Clean and Affordable Power

To enhance natural gas use in new and emerging power generation markets, the Federal Government and industry should work together to explore central station and distributed generation markets for high-efficiency advanced natural gas technologies such as advanced gas turbines and fuel cells. To allow distributed generation technologies to become a significant part of the new intergrid, we must develop enabling technologies such as advanced meters, control and sensing electronics, and interconnection hardware. The Federal and State Governments should also streamline regulations to provide reliable and safe transmission and distribution capacity for both electricity and natural gas, while minimizing environmental impact. **Table ES-2 shows the objectives and strategies associated with this goal.**

**Table ES-2. Clean and Affordable Power**

| R&D Objectives | Strategies |
|---|---|
| Advanced Power Systems | • Develop modular efficient systems with low life-cycle costs (microturbines, solid oxide, proton exchange membrance and molten carbonate fuel cells, hybrid fuel cell/gas turbine systems, natural gas engines, next-generation gas turbine systems).<br>• Create a technology development program of cross-cutting research in combustion systems, materials and manufacturing, fuel processing, power electronics, and sensors and controls to support the development of emerging systems.<br>• Demonstrate systems that produce fewer, and ultimately zero, emissions of air pollutants.<br>• Identify and foster incentives to reduce the risk for adoption of advanced power technologies; educate regulatory entities on the benefits of specific technologies; encourage favorable financial incentives to accelerate commercial introduction.<br>• Develop systems that provide high-quality power for industries that are sensitive to power disruptions (cellular communications, airline reservations, credit card transactions, brokerage operations, financial transactions, etc.). |
| Enhancing Utility Infrastructure | • Foster development of technologies and products to identify, monitor, and prevent pipeline damage.<br>• Develop technologies to ensure structural integrity, reduce internal corrosion, and improve guided boring and advanced trenching. Develop advanced metering and measurement technologies.<br>• Develop risk management tools and models to locate and remediate pipeline problems.<br>• Develop advanced storage technologies to increase regional storage capacity and serve peak demand.<br>• Work with Federal and State agencies, industry and interested parties to reduce delays in Government regulatory and environmental compliance processes for pipeline and storage enhancements. |

## Efficient and Productive Energy Use

The Federal Government and industry should continue to increase the efficiency of natural gas use in the industrial, commercial, and residential sectors. In the last two decades, new combustor designs, gas turbines, combined heat and power applications, and appliances have realized significant gains in efficiency. Efficiency gains in these areas will continue to be a priority. Federal programs need to provide incentives to employ efficient, environmentally sound natural gas technologies. **Table ES-3 shows the objectives and strategies associated with this goal.**

**Table ES-3. Efficient and Productive Energy Use**

| R&D Objectives | Strategies |
|---|---|
| Clean and Efficient Vehicles | • Conduct R&D on low-cost, safe, and lightweight Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) fuel tanks and on advanced fuel storage media such as adsorbents.<br>• Develop new technologies to expand the infrastructure and improve the performance of existing CNG and LNG refueling stations.<br>• Remove technical barriers to the commercial development of a medium-duty CNG vehicle and a heavy-duty LNG truck.<br>• Develop an economic natural gas-to-hydrogen reformer for use at refueling stations.<br>• Work with industry to deploy natural gas vehicles in niche markets with a high probability of success to overcome negative perceptions of natural gas as a transportation fuel. |
| Efficient and Affordable Buildings | • Conduct cost-shared R&D of energy-efficient building equipment, materials, and analytic tools. Use partnership programs like DOE's *Building America, Rebuild America, Energy Smart Schools,* and DOE/EPA *Energy Star* to aid in deployment and demonstration.<br>• Conduct cost-shared R&D of components and packaged systems for the production of electrical power, cooling, and heating from natural gas, using advanced power generation technologies (turbines, fuel cells, reciprocating engines) together with advanced energy recovery and utilization technologies.<br>• Develop and demonstrate fuel cell components and systems for cogeneration in buildings.<br>• Conduct cost-shared R&D of desiccant technology to be integrated into building air-conditioning systems for humidity control to improve indoor air quality. |
| Clean and Productive Industries | • Establish cooperative programs to develop technologies that provide cost-effective approaches to improving the efficiency of gas-fired industrial systems.<br>• Establish cooperative programs to develop technologies that enhance the radiant heat transfer properties of natural gas flames.<br>• Improve communications with all sectors of the natural gas consuming industries to facilitate the introduction of high efficiency, clean natural gas technologies. |

## Energy Information and the Natural Gas Industry

The Department aims to serve public policy makers and decision makers with high-quality, timely, and comprehensive natural gas information so that they can assess the gas industry's performance. The Energy Information Administration (EIA) is primarily responsible for developing, disseminating, and analyzing energy information. Using this information base, the Department as a whole will work to promote a better understanding of natural gas programs and policies among all parties. **Table ES-4 shows the objectives and strategies associated with this goal.**

**Table ES-4. Energy Information and the Natural Gas Industry**

| R&D Objectives | Strategies |
|---|---|
| Comprehensive Natural Gas Information | • Improve effectiveness of the Government in natural gas policy and technology development.<br>• Enhance communication among Federal, State and local agencies, tribes, industry, lawmakers, and other stakeholders on issues related to natural gas supply and demand. This includes actions that can be taken to mitigate short-term energy emergencies and to establish a balanced, long-term approach to responsibly developing the nation's natural gas resource base.<br>• Revise the natural gas data system to capture relevant industry and market activities and enhance data collection to maintain comprehensive coverage [*Next Generation* Natural Gas* $(NG)^2$].<br>• Establish an "Information Channel" approach on the EIA Web site. |

# Introduction

Clean, affordable, reliable, secure energy is vital to the health and well being of Americans and the U.S. economy. Natural gas—domestically abundant, clean burning, and affordable—will be the fuel of choice in meeting the expanding energy demand. Over the next 20 years, natural gas will play an increasingly significant role in meeting U.S. energy needs cleanly, affordably, and reliably.

Natural gas is the cleanest of the fossil fuels. Because of low capital costs, high efficiencies, and lower emissions for end use equipment, natural gas is increasingly favored in the new power generation technologies. Also, because it is available domestically, the supply is more secure than are other sources that must be imported, and will lead to a better national economy.

However, there are challenges to be overcome in using natural gas. Demand for natural gas has increased more rapidly than anticipated. This increase places greater demands on the energy supply, transport, and end use sectors. Price volatility has increased, and concerns about regional or transient supply shortages have emerged.

To take full advantage of the benefits of increasing use of natural gas, the Department of Energy is putting forth this *Natural Gas Strategic Plan*. This plan is intended to aid in the development of a national strategy to integrate the Government's programs and policies.

The following sections analyze the market situation and discuss strategies to reach the R&D goals. Appendixes A through D provide additional information. Appendix E lists references and Appendix F provides a glossary.

# Situation Analysis

Over the next 20 years, natural gas demand is expected to grow from 22 trillion cubic feet (Tcf) to almost 35 Tcf;[16] consumption will increase in every sector: electricity generation, residential, commercial, transportation, and industrial. This section analyzes the projected outlook for natural gas markets over 20 years: what the growth is expected to be in the various market sectors; factors that will influence the market; and the likely balance of supply, demand, and price.

***Note:*** The numbers presented in this section represent *projected* growth.

## Projected Growth in Market Sectors

In 1999, the United States consumed 22 Tcf of natural gas, which accounted for 23 percent of domestic energy consumed. Consumption of natural gas is projected to rise to almost 35 Tcf in 2020.[17] Recent studies projected significant increases in demand for natural gas:

- **EIA**—almost 32 Tcf in 2015 and 35 Tcf in 2020.[18]
- **NPC**—almost 29 Tcf in 2010 and 31 Tcf by 2015.[19]
- **American Gas Association**—35 Tcf by 2020.[20]

All sectors are projected to increase (**Figure 1**) but the focus will shift. The greatest increase will come from electricity generation (see **Table 1**).

By 2020, the residential and commercial sectors combined should increase by a projected 2.4 Tcf.

**Short-Term Domestic Supply: ↓ Down**
- Several years of relatively low prices before 2000
- Exploration and drilling for new sources slowed
- Production capacity

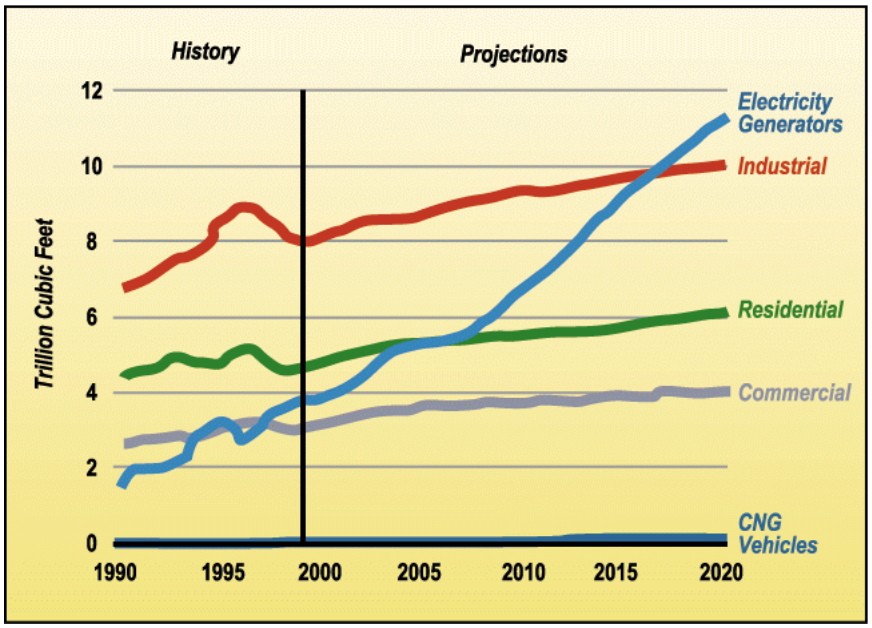
**Current Demand: ↑ Up**
- Growing economy
- Increasing gas-generated electricity

**Current Price: ↑ Up**
- Short-term domestic supply constraints
- Winter
- Low volumes in storage

**Long-Term Domestic Supply: ↑ Up**
- Recent record prices
- Rebound in exploration and developmental drilling
- Already increased production capacity slightly
- Expected increase in exploration and production budgets
- U.S. production increase to 29 Tcf
- Imports increase
- Gas supplies and pipeline infrastructure for the anticipated market expansion

**Expected Demand: ↑ Up**
- Gas consumption by electricity generators increases by a factor of 3 by 2020.
- Total gas consumption rises from 22 Tcf in 1999, to almost 35 Tcf by 2020

**Expected Price: ↓ Down, then ↑ Up**
- Springtime prices
- Increase in supply
- Production capacity increases.
- Long-term price remains around $3.00 (1999 $/Mcf)




Source: DOE/EIA, *Annual Energy Outlook 2001 with Projections to 2020*. December 2000, p. 96.

**Figure 1. Natural Gas Use Is Projected to Increase Most Dramatically for Electricity Generation**

**Table 1. Increase by Sector ***

| Market Sector | Percent of Total Gas Consumption | | | | Comment |
|---|---|---|---|---|---|
| | 1999 | | 2020 | | |
| | % | Tcf | % | Tcf | |
| Residential and commercial | 36.4 | 7.79 | 29.3 | 10.16 | Increases significantly during summer |
| Electricity generation | 17.7 | 3.78 | 32.6 | 11.34 | Increases by a factor of 3 |
| Industrial | 37.1 | 7.95 | 29.3 | 10.18 | |
| Transportation | 0.01 | 0.02 | 0.43 | 0.15 | |

*DOE/EIA. *Annual Energy Outlook 2001 With Projections to 2020.* Washington, DC: December 2000. Publication DOE/EIA 0383(2001), p. 128.

## Factors Influencing Markets

National energy security needs, economic and environmental conditions, technology development, and consumer demands will affect the long-term development of the energy market.

- **National Energy Security Needs**—The nation's supply of energy must be stable and the energy infrastructure must be secure. The best way to ensure a stable supply of energy is to ensure a supply that does not depend on other nations. The infrastructure itself is susceptible to natural, accidental, and intentional threats, to both physical and cyber assets.

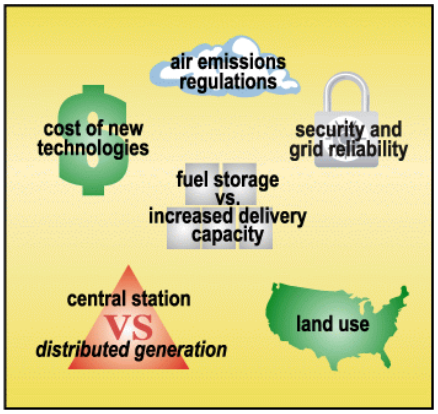
- **Economic and Environmental**—The main factor in the leap in the natural gas market is the increase in *gas used to generate electricity*. Over the next 20 years 1,300 new power plants will need to be built to meet increasing consumer demand. For new electrical plants, gas technologies provide lower capital costs, shorter construction lead times, higher efficiencies, and lower emissions. With coal technologies, capital costs are higher, construction lead times are longer, efficiencies are lower, and emissions are higher. With nuclear energy, capital costs are higher, construction lead times are longer, and public opinion tends to be negative. Renewables (wind, solar, biomass fuels) are not yet at the stage of providing large amounts of base load power.

- **Technology Development**—According to the American Gas Association, the increased market for natural gas will come from distributed generation, gas cooling, combined heat and power systems, natural gas vehicle fleets, and new gas-fired central station power plants. Adding new gas turbines and combined-cycle facilities will expand the electrical generating capacity.

- **Consumer Demands**—Consumer demand is expected to increase slightly as well. Residential prices are expected to remain competitive with prices of other fuels. It is projected that more and more consumers will turn to natural gas for heating. Homes heated with natural gas will increase more than three times than homes heated by other sources.

Combined, the residential and commercial sectors add a projected demand of an additional 2.4 trillion cubic feet from 1999 to 2020.[21]

Multiple factors (see figure) must be considered in meeting the demand of the electric power sector: the mix of central station vs. distributed generation; the cost of new high efficiency, low emissions gas technologies (e.g., fuel cells, gas turbine combined cycle); fuel storage vs. increased delivery capacity; air emissions regulation (SOx, NOx, HAP's, $CO_2$); land use; grid reliability and security.

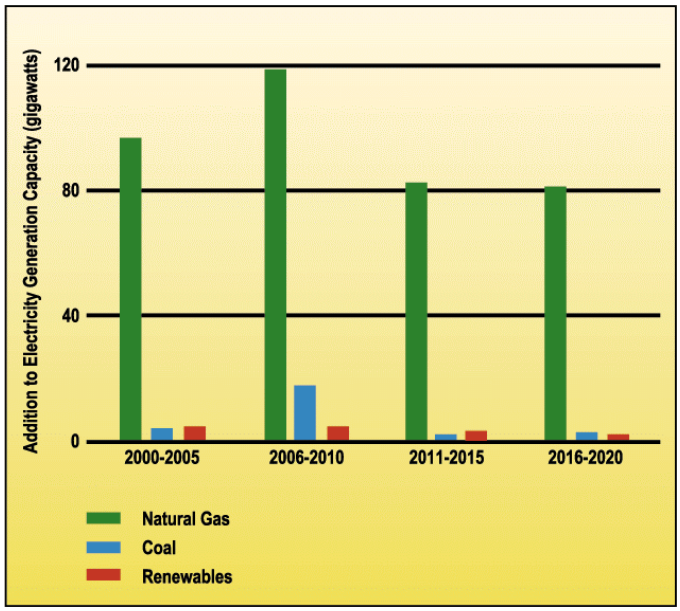


## Projected Supply, Demand, and Price

Supply, demand, and price are three elements that are inextricably woven together. Will the projected supply be able to meet the increase in demand? Will the transportation infrastructure be able to carry the increased supply? How will prices be affected by the increase, and how will the prices affect the supply and demand?

### *Demand–Driven by gas-fueled electricity generation*

Much of the demand will be driven by the growing use of gas for electricity generation. For the electric generation sector (excluding cogenerators), consumption is estimated to increase by 3.2 percent from 1999 and is expected to increase by 5.4 percent above its 2000 level in 2001.[22] In 2020, the plants will need to add almost 400 gigawatts more total capacity than they had in 1999, an increase of approximately 53 percent. Of that new capacity, 92 percent is projected to be combined-cycle or combustion turbine technology fueled primarily by natural gas.[23] (See **Figure 2**.)




Source: DOE/EIA, *Annual Energy Outlook 2001 with Projections to 2020*, December 2000, p. 73.

**Figure 2. About 1,300 New Power Plants Needed by 2020 with Vast Majority Powered by Natural Gas**

As demand increases, so will the impact on natural gas supply and transportation infrastructure.

## Supply–Affected by technology, price

The natural gas *supply* is expected to accommodate the anticipated market demand of more than 28 Tcf by 2010.

In April 1998, to meet the growing demand for gas, the Administration's Comprehensive National Energy Strategy established a goal of increasing domestic natural gas supply by 6 Tcf by the year 2010. The question is whether technology will improve adequately to develop and produce enough natural gas and whether recoverable resources will be sufficient to meet the demand.

Technology is a vital contributing factor that will shape the industry's ability to find and develop resources and to manage costs to supply gas at reasonable prices. As an extension of historical trends, it is assumed that technology and operations will continue to improve through the forecast period, given adequate sources of financial support for R&D.

For **domestic** supply, the increase is projected to come primarily from offshore and unconventional sources. Innovative, cost-saving technology and large finds, particularly in the deep waters of the Gulf of Mexico, have renewed interest in these offshore areas.

Technically recoverable natural gas resources are expected to be adequate to sustain growing production volumes for many years. As of January 1, 1999, technically recoverable resources were 1,281 Tcf.[24]

Additional large volumes of gas are located in the North Slope region of Alaska. These volumes exceed 30 Tcf in already identified fields. At present these resources lack an economically viable way to reach major consuming markets. However, the three major North Slope natural gas producers have recently announced a $75 million effort over the next year to work on the design, costs, permitting, and viability of a pipeline to deliver the gas to the continental United States. If land use restriction was adjusted, additional large volumes could be produced at reasonable prices.

Current Average Well Production = 157,100 $ft^3$/day

Current Number of Wells = 306,000

To meet future need of 35 Tcf (2020) (13.6 Tcf more than 1999's 21.43 Tcf) the United States would need an additional 235,000 wells at current average production rates.

Source: DOE/EIA. *1999 Annual Energy Review*. Table 6.4.

To meet the projected 2010 gas market of 28 Tcf, natural gas producers must provide an average of 2,000 to 2,100 miles of new gas transmission each year.

Cost is approximately $32.2 billion to $34.4 billion to construct required pipeline and storage infrastructure.

By 2015, more than 14 million new customers will be connected to the natural gas grid.

By 2020, the United States will need 1,300 new powerplants, 90% of which will be gas-fired.

**Imports** will supplement the domestic gas supply. Net natural gas imports are expected to grow from 16 percent of total gas consumption (3.5 Tcf) in 1999 to 17 percent (5.8 Tcf) in 2020.[25] Most of the increase is attributable to imports from Canada, primarily from western Canada and Sable Island.

Mexico is unlikely to become a future source. They will be converting their power plants from heavy fuel oil to natural gas, in compliance with environmental regulations. It is unlikely that Mexico's indigenous production can be increased enough to satisfy their rising demand, much less exporting to other countries.

Liquified natural gas (LNG), both domestic and imported, provides another source of gas. LNG is more expensive than natural gas, however. Given the projected low natural gas prices in the continental United States, LNG is expected to supply just 2.5 percent of U.S. gas consumption in 2020.[26]

## *Price–Expected to rise slowly and settle at $3.00 per thousand cubic feet*

In inflation-adjusted terms, average gas prices in 2000 are comparable to those seen in the early to mid-1980s, but lower than those seen in the early 1980s. In early 2000, high oil prices caused gas consumption to increase. The supply was low at the time, owing to low prices for several years. The increase in demand, together with a low supply, resulted in rising natural gas prices.

Spot wellhead prices have recently exceeded $9.00 per thousand cubic feet. This high price has caused exploration and developmental drilling to rebound. Spurred by higher prices and greatly improved revenues, many natural gas producers are expected to increase their exploration and production budgets in 2001, again increasing the supply.

Although the recent price increase has been severe, the primary causes are transitory. As the winter of 2000/2001 comes to a close, seasonal demand will decrease. Also, the increased drilling for gas already seems to be yielding gains in production. The Railroad Commission of Texas indicates that through July 2000, gas production increased by 0.8 percent.[27] This signifies a modest turnaround in a key producing region, Texas, which accounts for 30 percent of total U.S. market gas production. U.S. dry natural gas production in 2000 increased by 3.2 percent over 1999 levels, rising from 21.7 Tcf to 22.7 Tcf. During the same period, however, consumption grew by 4.4 percent.

# Strategy

***Vision:*** *By 2020, the U.S. public is enjoying greater environmental and economic benefits from the use of natural gas."*

To provide a secure energy future, the United States depends on a portfolio of energy choices for all consumers. Key in this energy portfolio is natural gas.

The electricity, natural gas, and telecommunications industries are converging, creating a new "intergrid." Environmental regulation and national energy security will continue to shape the energy market. System reliability and critical infrastructure will become increasingly important.

## Overarching Strategy: Integrate Policy, Regulation, Technology, and Incentives

The fundamental and complex changes in the energy marketplace and the need to increase the natural gas supply will involve many organizations, both governmental and industrial. At the Federal level, a broad array of departments and agencies must cooperate to form policies, regulations, technology investments, and incentives. These organizations may have competing or conflicting policies and regulations. The NPC recognized the importance of this cooperation when it recommended that:

**Examples of departments and agencies involved:**

**Natural Gas Supply**

- Department of the Interior
- Bureau of Land Management
- Minerals Management Service
- Bureau of Indian Affairs
- U.S. Geological Survey
- Department of Agriculture–Forest Service
- Department of Energy
- Department of Commerce–Federal Trade Commission
- Department of Treasury–Treasury
- Environmental Protection Agency

**Delivery Systems and Use**

- Department of Energy
- Federal Energy Regulatory Commission
- Treasury
- Department of Transportation–Office of Pipeline Safety

**Environmental Regulation of Industry**

- Environmental Protection Agency
- Federal Energy Regulatory Commission
- Department of Energy provides technologies associated with environmental compliance

**Broad cooperation will be needed to address the issues:**

- Need to prevent widespread power outages and network failure.
- Restructuring and deregulation require streamlined approach in policy and regulation.
- Need new technology for products, services, and systems for control, measuring, monitoring, storage, security, and delivery:
  - New pipelines must be built and existing ones maintained.
  - Increasingly complex reservoirs and challenging operational environments.
  - Investors and industry are no longer assured of the recovery of capital.
- Trade relations with foreign governments.


**R&D INVESTMENT**
Seismic, diagnostics, & imaging technologies.
Advanced drilling technologies.
Gas hydrates research.
Gas upgrading technologies.

**FEDERAL LANDS ACCESS POLICIES**
Continual on-shore/off-shore policy review.
Privatization.
• Elk Hills Naval Petroleum Reserve
• Naval Oil Shale Reserves

**FINANCIAL INCENTIVES**
Deep water royalty relief and royalty simplification.
100% expensing of G&G costs.
Expensing of delay rental payments.
AMT and percentage depletion tax relief for small operators.
Guaranteed loan program for small domestic oil and gas producers.

> **"Government and industry must take a leadership position in establishing—at the highest level—a strategy for natural gas in the nation's energy portfolio. An Interagency Work Group on Natural Gas should be established to work with industry and other stakeholders to formulate the strategy and resolve issues."**[28]

In response to the NPC's recommendation, the White House established the White House Interagency Working Group on Natural Gas and the DOE produced this *Natural Gas Strategic Plan*. Because its mission is energy related, the DOE is the primary Federal department providing policy recommendations and technical assistance to the interagency task force.

The recently established National Energy Technology Laboratory's (NETL) Strategic Center for Natural Gas (SCNG) will support development of policies and technologies to improve the ways gas is found and produced and delivered to the marketplace, as well as new ways to make the use of natural gas cleaner, safer, and more efficient. The SCNG could be a key resource for coordinating, developing, and analyzing interagency working group proposals.

By linking the technology investment with policy, regulatory, and financial initiatives and with interagency cooperation, DOE can provide a logical and more predictable path toward the vision.

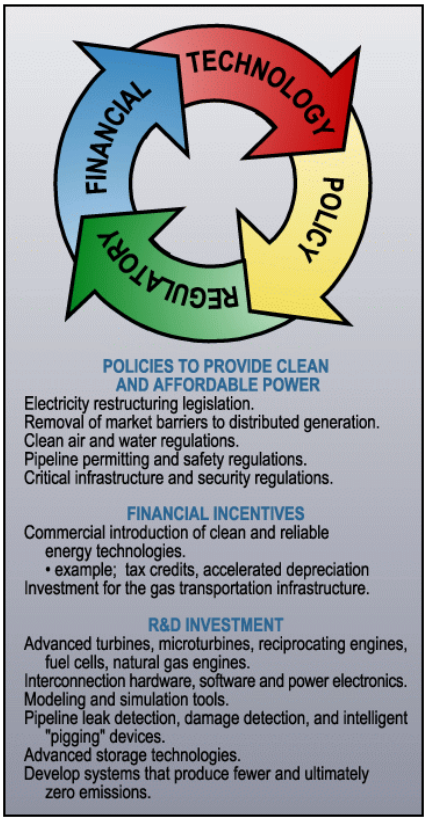
The DOE identified three overarching challenges for energy policy makers:[29]

## Maintaining America's Energy Security

To maintain America's energy security in global markets, the United States must have a reliable and diverse energy supply in which natural gas is an important fuel source. This requires access to U.S. natural gas resources, reducing the costs of exploration and production, and minimizing environmental impact. The sidebar shows examples of the types of policies, incentives, and investments that must be linked to maximize effectiveness in this area.

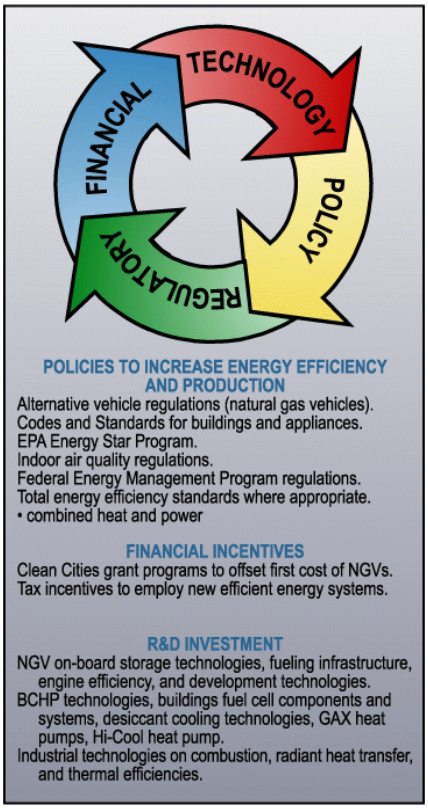
### Harnessing Competition in Restructured Energy Markets

To harness the forces of competition in restructured energy markets, the United States will need to invest in programs that provide clean and affordable power. The sidebar shows examples of the types of policies, incentives, and investments that, working together, would enable focus on advanced power systems and energy systems reliability.




### Mitigating Environmental Impact

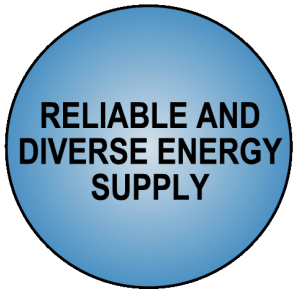
To mitigate the environmental impact of energy use, programs must be pursued to increase the efficiency and production of energy systems. This includes programs focusing on clean and efficient vehicles, efficient and affordable buildings, and clean and productive industries. The sidebar shows examples of the types of links that would enable such programs.




## Portfolio of DOE Natural Gas Strategies

The Department of Energy has based this *Natural Gas Strategic Plan* on broad, high-level policy principles, goals, and challenges presented in the *Comprehensive National Energy Strategy*[30] and *Powering the New Economy*,[31] and DOE's *Energy Resources Portfolio*.[32] Many of the proposed strategies center largely on key technology developments. This focus is due in part because DOE is the lead Federal agency in this arena.

This section presents specific strategies that address the R&D goals and objectives and challenges.




# Goal: Reliable and Diverse Energy Supply

## Objective 1: Enhancing Domestic Supplies

**Aim:** To advance technologies and policies that provide industry with the supply to meet demand in 2020, while protecting the environment.

| Supports | |
|---|---|
| **CNES Goal/Objectives** | **NPC Study Findings** |
| • **CNES Goal II, Objective 2** – Ensure energy system reliability, flexibility, and emergency response capability.<br>• **CNES Goal III, Objective 1** – Increase domestic energy production in an environmentally responsible manner.<br>• **CNES Goal IV, Objective 2** – Develop technologies that expand long term energy options. | • Sufficient resources exist to meet growing demand well into the 21st century.<br>• Restricted access could limit the availability of supply.<br>• A healthy oil and gas industry is critical for natural gas supply to satisfy expected increases in demand.<br>– Adequate financial performance must be demonstrated to compete for and attract financial investment.<br>– Aggressive pro-active workforce planning is essential.<br>– New drilling rigs must be built.<br>• Investment in research and development is needed to maintain the pace of advancements in technology. |

RELIABLE AND DIVERSE ENERGY SUPPLY

# Challenges and Strategies

Analyses by the U.S. Geological Survey and Minerals Management Service show that the United States has extensive technically recoverable natural gas resources – about 1,500 Tcf. Over the past 20 years technology advancements have reduced the cost and environmental impact of finding and producing oil and gas. However, the United States is a mature producing area and the most accessible, easiest to find, and most economic reservoirs have been developed. Without major technological advances and Federal policy changes, industry may not be able to supply the future 35 Tcf demand at reasonable prices. The specific challenges are:

## ➤ Challenge 1: Enable Environmentally Responsible Gas Production

Many of the future resources are in environmentally sensitive areas, requiring less intrusive exploration and production technologies and better waste management approaches. A review of the scientific basis for regulations is also needed.

### *Strategy*

**Advance technology development for:**

1. Drilling wells with a smaller "footprint".
2. Ensuring safe operations in gas hydrate prone areas.
3. Developing offshore technologies for deepwater operations and deep formations in shallower waters.
4. Improving waste minimization and environmental compliance technologies. Develop data for science-based regulations. Work with States and organizations such as Groundwater Protection Council to make more cost-effective regulatory and policy decisions regarding gas supply.

### Deep Water Recovery

The deepwater of the Gulf of Mexico (GOM) holds enormous potential to help meet the United States growing demand for natural gas. Between 1990 and 1999, natural gas production from deepwater GOM (>1000') has increased 26-fold while onshore and shallow-water offshore gas production have grown less than 6 percent. This rapid increase in deepwater production has been stimulated by technology developments in reservoir detection and drilling and incentives like the Deep Water Royalty Relief Act. Joint R&D efforts could provide an economic incentive for private industry to invest in breakthrough technologies, and expand exploration and development activities in the GOM. DOE has completed an offshore technology roadmap with industry and is developing a program plan.

(www.fe.doe.gov/oil_gas/reports/ostr/roadmap.html)

RELIABLE AND DIVERSE ENERGY SUPPLY

## Challenges and Strategies (Continued)

### Challenge 2: Increase Production of Non-Conventional Resources

Future gas reserves may come from non-conventional resources including tight gas sands, fractured shales, and methane hydrates that are not economic to produce using current technology. Deep or geologically complex reservoirs or those in ultra-deep water will provide a growing share of production. To locate these resources, remote sensing and other geophysical imaging technologies must be improved. To economically and safely reach targets in hostile environments, drilling, completion, and stimulation technologies must be improved. Advances are required in production technologies to ensure safe operations in areas underlain by hydrates and to reduce environmental impacts of operations.

#### *Strategy*

Develop advanced technology for: 1) reservoir detection and imaging, including surface and wellbore geophysics; 2) drilling deeper, faster, and cheaper; 3) production of methane from hydrates; 4) more efficient production in high-risk areas; and 5) analysis of tax incentives for non-conventional resources.

### Challenge 3: Improve Access

15 percent of the gas resource is on Federal lands with restricted access: NPC estimates that 137 Tcf (41 percent) of Rocky Mountain and 76 Tcf of offshore technically recoverable resources are subject to prohibitions or impediments to access.[33]

Both regulatory and technology solutions would be needed to increase access to the resource where environmentally appropriate.

#### *Strategy*

Conduct research, development and demonstration with industry, universities, and national labs to advance technology development to reduce the number and impact of wells needed to access gas on Federal lands. Commission the Interagency Working Group to explore environmentally benign ways to improve access to resources on Federal lands.

### Challenge 4: Increase Availability of Remote Gas

Alaska North Slope has more than 30 Tcf in developed fields. Undiscovered technically recoverable conventional resources are estimated to be about 70 Tcf and Alaska gas hydrates may contain another 169,000 Tcf of gas in place. Cost effective gas-to-liquids technology, a pipeline, or both, will be required to bring this gas to market.

#### *Strategy*

Stimulate development of gas-to-liquids technology, and facilitate pipeline development by optimizing permitting procedures through interagency cooperation.

RELIABLE AND DIVERSE ENERGY SUPPLY

# Challenges and Strategies (Continued)

## Challenge 5: Increase Gas Imports

In order to meet demand over the next 20 years, EIA estimates that imports from Canada will grow from about 3 Tcf per year to more than 6 Tcf and imports of Liquified Natural Gas (LNG) will grow from 20 to 330 Bcf over the period from 1998 to 2020. Mexico is expected to continue to be a net importer of U.S. gas.

### *Strategy*

Resume annual energy meetings between the United States and Canada. Increase coordination with Mexico. Continue to expedite natural gas and LNG import authorizations.

## Challenge 6: Improve Gas Upgrading Technology

An estimated 22 percent of future gas production will be below pipeline quality due to concentrations of $CO_2$, nitrogen, and sulfur. More efficient upgrading technologies are needed to make this gas commercially usable.

### *Strategy*

Advance technology development for more efficient and environmentally benign gas upgrading technologies for removal of water, nitrogen, $CO_2$, and sulfur.

## Challenge 7: Increase Use of Advanced Technology by Small Companies

Oil and gas exploration has a high level of risk – about 57 percent of exploration and 20 percent of development wells are unproductive and many other wells are only marginally economic. The first use of a new technology represents an even greater risk of unacceptably high cost or even failure. Financial incentives and field test demonstrations are needed to encourage adoption of new technology, especially among smaller companies that drill and operate a growing share (85 percent) of domestic wells.

### *Strategy*

Conduct cost shared field demonstrations with industry to demonstrate improved reservoir imaging and more efficient production technologies to reduce risk of technology application and enhance utilization.

Assess the financial costs/benefits of Federal incentives for use of new technology by small independents.

Increase availability of existing subsurface data by providing internet-based reservoir atlases and basin assessments.

RELIABLE AND DIVERSE ENERGY SUPPLY

# Challenges and Strategies (Continued)

## Challenge 8: Stimulate Investment in Exploration and Production

NPC has estimated that adequate supply growth will require average capital expenditures of $39 billion per year from 1999 through 2015, a 45-percent increase over the $27 billion annual average from 1991 through 1998. NPC expresses concern that this level of investment is unlikely, given the upstream sector's past history of poor return on investment. Changes in Federal royalties and financial regulations could be required for the gas exploration and production industry to be competitive with other investment opportunities.

### *Strategy*

Work with industry and other government agencies to develop financing, policies, and regulations that support increased gas production while protecting the environment.

Encourage legislation to allow 100-percent expensing of all G&G costs in the year incurred and expensing of delay rental payments.

Encourage Department of the Interior rulemaking for deepwater royalty relief.

Encourage participation in the Emergency Oil and Gas Loan Program.

Analyze additional incentives to increase production.

## Challenge 9: Increase R&D Funding

The technology advancements that have spurred gas production and cut costs in the 1990s were stimulated by prior research efforts. However, industry spending on R&D has declined due to low prices in the 1990s. R&D spending is expected to decline further with industry mergers and with the phase-out of FERC-authorized funding for the Gas Research Institute (now GTI). (This funding totaled $145 million in 1999 and phases out in 2004.) Increases in both Federal and industry R&D spending as well as innovative approaches to conducting R&D will be required.

### *Strategy*

Explore advances in other industries that may be applicable to the gas industry.

Facilitate greater interaction between research and investment community in a timely manner to demonstrate the benefits of new technologies.

Coordinate with oil recovery R&D programs to leverage applicable technologies and enhance production of associated gas.


# Challenges and Strategies (Continued)

## Challenge 10: Expand Skilled Labor Pool

Periods of low prices in the 1980s and 1990s have reduced exploration and production employment by more than 50 percent. Simultaneously, university enrollment in petroleum-related disciplines, geoscience and petroleum engineering, has declined. These factors could limit the ability of industry to increase exploration and production activity. Large numbers of retirements over the next 10 years will exacerbate this problem.

### *Strategy*

Facilitate improved communication between industry, academia, and government to develop a sufficient stream of qualified scientists and engineers.

Support basic and applied research at universities and national labs that provides advanced training and financial support to students.


## Goal: Reliable and Diverse Energy Supply

### Objective 2: Producing Clean Fuels

**Aim:** To develop, demonstrate, and deploy technologies and systems that will produce future transportation fuels from natural gas, which, when utilized in advanced highway vehicles, will result in improved energy security, environmental quality, and economic competitiveness.

**Supports**

| CNES Goal/Objectives | NPC Study Findings |
|---|---|
| • **CNES Goal I, Objective 2** – Significantly increase energy efficiency in the transportation, industrial, and buildings sectors by 2010.<br>• **CNES Goal II, Objective 1** – Reduce the vulnerability of the U.S. economy to disruptions in oil supply.<br>• **CNES Goal III, Objective 1** – Increase domestic energy production in an environmentally responsible manner.<br>• **CNES Goal III, Objective 2** – Accelerate the development and market adoption of environmentally friendly technologies.<br>• **CNES Goal IV, Objective 2** – Develop technologies that expand long-term energy options. | • **Recommendation 2** – Establish a balanced, long-term approach for responsibly developing the Nations's natural gas resource base.<br>• **Recommendation 3** – Drive research and technology development at a rapid rate. |

RELIABLE AND DIVERSE ENERGY SUPPLY

# Challenges and Strategies

## ➤ Challenge 1: Reduce emissions in the transportation sector

Of manmade air emissions in the United States, transportation produces nearly 80 percent of the carbon monoxide, more than half of the nitrogen oxides, and 40 percent of the volatile organic compounds. Transportation sector carbon emissions are about 490 million tons or approximately one third of the total U.S. emissions. EPA's proposed schedules for Tier II standards implementation for diesel fuels require that these technologies be available much sooner than anticipated. Fuels that meet future requirements for toxic materials and ultra-fine particles must be examined.

***Strategy***

Environmental improvements will be achieved by: 1) participation in the coordinated management, planning and implementation of the Department's Ultra-clean Transportation Fuels Program, and 2) effective utilization of R&D efforts in coordinated activities to produce the data and/or technology needed to support the development and commercialization of fully integrated fuels, engines, and emissions control systems.

## ➤ Challenge 2: Consumer acceptance of new fuel forms

Recent economic and environmental issues concerning alternate fuels (e.g., methanol), fuel blends (e.g., ethanol/diesel) and fuel additives (e.g., MTBE) are generating concerns about the future of these fuels and systems. Although advancements in refining technology and new sources of alternate fuels will be required to meet market and public demands, they will require consumer acceptance to become commercially viable.

***Strategy***

Gain acceptance through: 1) coordinated and focused outreach efforts providing up-to-date information for the potential market and user community, and 2) sufficient testing of alternate fuels and fuel combinations to create and support consumer confidence in the efficiency and environmental characteristics of fuels.

## ➤ Challenge 3: Integrate cooperative efforts by all transportation sectors

Interactions between the fuel-sensitive elements of engines, the on-board emission control systems, and the fuels generated from natural gas and/or natural gas/petroleum based fuel blends require a close coordination between those sectors of industry with primary responsibilities in each of these areas. Such coordination is essential if the transportation sector is to meet the challenges of environmental performance and energy security.

***Strategy***

Integrate through: 1) one-on-one, pro-active dialogues with key industry representatives in Executive Seminars, work shops and jointly funded activities, 2) participate in and support joint industry/government steering committees that guide combined and separate R&D efforts, 3) fund joint projects that provide incentives for industry to build and operate first-of-a-kind facilities.

## ➤ Challenge 4: Reduce dependency on imported petroleum

The Energy Information Administration projects that the U.S. demand for petroleum products will grow by 5 million bpd to 25 million bpd by 2020.[34] This trend can be significantly reduced by recovering and using "stranded" or "associated" gas.

***Strategy***

Develop alternate sources of supply by 1) coordinating with industry in the identification and development of comprehensive options for commercializing and marketing regional energy resources, 2) selecting, developing, and implementing the technology needed to optimize the product slate to meet adjacent and regional demands, and 3) prioritizing these R&D activities to make stranded and associated gas a viable option as an alternative liquid fuel.


## Goal: Clean and Affordable Power

### Objective 1: Advanced Power Systems

**Aim:** To reduce fuel use and the volume of pollutants and greenhouse gases emitted per unit of useful electric power produced while maintaining an adequate, reliable, and affordable supply of low-cost power.

| Supports | |
|---|---|
| **CNES Goal/Objectives** | **NPC Study Findings** |
| • **CNES Goal I** – Improve the efficiency of the energy system.<br>– Objective 1: Support competitive and efficient electric systems.<br>– Objective 2: Significantly increase energy efficiency in the transportation, industrial and buildings sector by 2010.<br><br>• **CNES Goal III** – Expand future energy choices.<br>– Objective 2: Accelerate the development and market adoption of environmentally friendly technologies. | • **Recommendation 3** – Drive research and technology at a rapid rate. *"The government should promote high-efficiency gas technologies such as fuel cells, gas cooling, and high-efficiency turbines."* |

CLEAN AND AFFORDABLE POWER

## Challenges and Strategies

The goals for Advanced Power Systems are based on developing clean, cost-effective solutions to provide reliable electrical, thermal and mechanical energy. These highly efficient technologies will meet existing and growing demands in the residential, industrial, commercial, and utility sectors. In addition, significant focus on distributed generation technologies is needed to meet the needs of the future energy marketplace.

### Challenge 1: Improve the efficiency of energy systems

Improve the efficiency of energy systems by making more productive use of energy resources to enhance overall economic performance. Develop systems to provide low cost affordable electricity to sustain growth of the U.S. economy.

#### *Strategy*

Develop modular efficient systems with low life cycle costs. Provide financial support to developers of emerging systems with affordable capital cost, operating & maintenance cost, and high reliability and availability. Emerging systems include:

- **Microturbines** (25kW to 1,000kW) with: 1) conversion efficiencies of at least 40 percent; 2) NOx emissions of less than 7 parts per million; 3) durability of 11,000 hours between major overhauls with a service life of 45,000 hours; and 4) system costs of less than $500 per kW.
- **Solid oxide and molten carbonate fuel cells** (250kW to 1,000kW) with: 1) conversion efficiency of 60 percent; 2) single digit NOx (e.g., less than 1 part per million); 3) fuel cell stack life in excess of 40,000 hours, and 4) initial system market entry cost of $1,000 to $1,500 per kilowatt.
- **Hybrid fuel cell/turbine systems** (1MW to 200MW) with: 1) conversion efficiencies of 70 percent or more; 2) single digit NOx; and 3) competitive system life and cost.
- **Natural gas engines** (500kW to 10MW) with: 1) 20 percent increase in fuel-to-electricity conversion efficiency; 2) 20 percent reduction in NOx, hydrocarbons, air toxics, and greenhouse gases; 3) engine overhaul intervals of 40,000 hours or more; 4) competitive capital cost; and 5) multi-fuel capability.
- **Next Generation Turbine Systems** (30MW to 300MW) with: 1) increase current turbine efficiencies from 38–42 percent up to 44–48 percent; 2) near zero levels of NOx, hydrocarbons, air toxics, and greenhouse gas; 3) greater than 15-percent reduction in cost to produce electricity; 4) competitive capital cost; and 5) multi-fuel capability.
- **Create a Technology Base Development Program** of cross-cutting research in combustion systems, materials & manufacturing, fuel processing, power electronics, and sensors & controls to support the development of emerging systems and identify new breakthroughs for future systems.

CLEAN AND AFFORDABLE POWER

## Challenges and Strategies (Continued)

### Challenge 2: Improve the environment while meeting the need for more electricity

Over the past 10 years electricity generation has increased 22 percent, while sulfur dioxide emissions have declined and nitrogen oxide emissions have increased only a few percent. The demand for electricity will continue to increase while current and potential environmental regulations for air, water, land and potentially greenhouse gases will require systems to produce fewer if not zero environmental pollutants.

#### *Strategy*

Develop and test systems that produce fewer and ultimately zero emissions to the environment. Demonstrate:

- **Turbine** systems with NOx emissions of: 1) less than 3 parts per million for Next Generation Turbine Systems; 2) less than 5 parts per million for Industrial Turbine Systems; and less than 7 parts per million for microturbine systems.
- **Fuel cell** systems with NOx emissions of less than 1 part per million.
- **Reciprocating engines** with 20 percent or more lower emissions.
- **Advanced systems** that recycle all byproducts and produce no emissions.

### Challenge 3: Reduce the regulatory, business, and financial barriers to market introduction

Siting power generation (land access, building codes & standards, etc.), especially in urban areas experiencing increasing demand for power, will become more difficult. Methods to overcome the high risk to commercializing emerging technologies are needed. The rapidly changing deregulated electricity market will create challenges to methods with regard to how power will be generated (central station vs. distributed generation), who will generate the power (merchant owners, self generators), how power is bought and sold (system dispatch/control, grid interconnection standards, etc.), and how projects will be financed.

#### *Strategy*

Identify and foster incentives to reduce the risk for adoption of advanced power technologies.

Educate regulatory entities on the benefits of specific technologies to obtain regulatory exemptions or minimize regulatory impediments. Implement Federal electricity deregulation policies, interconnect standards, building codes and standards and environmental siting and permitting requirements.

Encourage favorable tax incentives (e.g., credits, accelerated depreciation) at national, State, and local levels to accelerate commercial introduction. Encourage private sector investment through demonstration projects. Examine laws and regulations concerning intellectual property rights of developers to encourage investment. Encourage accelerated R&D funding.

Encourage adoption of “fuel-neutral” environmental standards for new systems.

CLEAN AND AFFORDABLE POWER

## Challenges and Strategies (Continued)

### Challenge 4: Provide improved infrastructure security and power quality to meet the needs of a rapidly growing "digital" market

Maintain a reliable secure electricity infrastructure to meet the needs to the nations increasing electricity demand. Distributed generation technologies will provide the opportunity for enhanced power quality in regional applications. Widespread application of sensitive electronic components will require high-quality reliable power for many businesses, beyond current reliability capabilities.

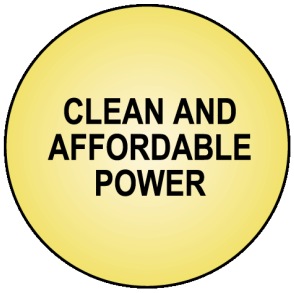
### *Strategy*

Develop satellite-synchronized measurement systems, advanced power electronics technologies, real-time system monitoring and control, and analyses to assess the interaction of competitive markets and electric reliability, in addition to integration of distributed energy resources on the transmission and distribution (T&D) system.

Develop interconnection hardware, software, and power electronics for emerging systems to ensure their safe and efficient operation in the nation's power grid.

Develop modeling and simulation tools to optimize the performance of interconnected energy systems to ensure system security and reliability.

Develop systems that provide high quality power for power sensitive industries such as: cellular communications, airline reservations, credit card transactions, and brokerage operations.




## Goal: Clean and Affordable Power

### Objective 2: Enhancing Utility Infrastructure

**Aim:** To advance technologies and policies that provide industry with the tools to improve the gas system infrastructure and expand gas storage facilities to meet a 35 Tcf market by 2020.

| Supports | |
|---|---|
| **CNES Goal/Objectives** | **NPC and Similar Study Findings**[35,36,37] |
| • **CNES Goal II, Objective 2** – Ensure energy system reliability, flexibility, and emergency response capability. | • **Finding 1** – Significant expansion and enhancements to the delivery system are required to serve the growing demand.<br>• **Finding 2** – Access issues impede installation of new infrastructure.<br>• **Finding 3** – New services are needed to serve a changing market.<br>• **Finding 4** – The restructured market changes the risks associated with investments for new infrastructures. |

The security, economic prosperity, and social well being of Americans depend on a complex system of interdependent energy infrastructures. The United States natural gas infrastructures, while robust and reliable, are facing operational challenges. The gas industry and its suppliers face significant regulatory, technology, environment, and market challenges to reach the 35 Tcf market by 2020. The specific challenges are:

CLEAN AND AFFORDABLE POWER

# Challenges and Strategies

## Challenge 1: Ensure pipeline infrastructure integrity, reliability, flexibility, and safety

NPC reports that technology, capital investment, consistent government policy, and faster, more predictable regulatory decisions are needed to enable timely and cost-effective infrastructure development and expansion to meet the growing gas demand while protecting human health and minimizing the risk to the environment.

### *Strategy*

- **Sensor Development.** Foster development of technologies and devices to identify, monitor, and prevent pipeline damage. This includes remote external leak detection technologies, damage detection inspection sensors, intelligent internal inspection "pigging" devices, and devices that are capable of sealing small dents and cracks in the pipeline wall.
- **Hardware and Materials Research.** Foster development of technologies to ensure structural integrity, reduce internal microbiological-influenced corrosion, improve guided boring technologies for directional drilling and advanced trenching technologies. Model and develop advanced flexible gas compressor systems. Develop new tools and advanced techniques for pipeline retrofits. Develop efficient and economic advanced pipeline gas meter and measurement technology.
- **Model Development.** Develop a risk-management evaluation model and criteria to locate active pipeline corrosion sites. Develop reliability analysis models, to be used to identify safety improvements.
- **Policy and Regulatory Process Improvement.** Initiate a mitigation forum process—acceptable to regulators, environmentalists, technology developers, landowners, consumer advocates, and industry users—that would evaluate new infrastructure technology and "better" management operating practices. Work with Federal and State agencies, industry and interested parties to reduce delays in government regulatory and environmental compliance processes.

## Challenge 2: Improve gas storage deliverability, operational flexibility, and expand regional storage capacity

The projected growth in gas demand has called into question whether regulatory actions and permitting processes can keep pace with the necessary increases for facilities in gas storage and delivery system. NPC reports that new services are needed to meet changing gas customer needs in response to the ongoing restructuring of the natural gas and electric markets. Many utility managers, in their efforts to reduce shareholder risk, have abandoned long-term resource planning and resisted making capital investments in pipeline operations and gas storage system development.

### *Strategy*

- **Policy & Regulatory Process Improvement.** Work with Federal and State agencies to reduce delays in government regulatory and environmental compliance processes. Work with State agencies to re-engineer underground gas storage facilities.
- **New Storage Concepts.** Foster development of advanced storage technologies to increase regional storage capacity and serve peak power generation and distributed generation markets.
- **Improved Deliverability and Verification to Meet Demand.** Conduct research on gas storage well deliverability enhancement. Foster research on re-engineering existing underground gas storage facilities. Foster research to minimize storage reservoir damage during well drilling and completion. Develop improved real-time storage inventory verification technologies.


## Goal: Efficient and Productive Energy Use

### Objective 1: Clean and Efficient Vehicles

**Aim:** To develop, in partnership with industry, technologies that enable the introduction of clean and efficient vehicle and transportation systems.

**Supports**

**CNES Goal/Objectives**

- **CNES Goal I, Objective 2** – Significantly increase energy efficiency in the transportation, industrial, and buildings sectors by 2010.
- **CNES Goal II, Objective 1** – Reduce the vulnerability of the U.S. economy to disruptions in oil supply.

EFFICIENT AND PRODUCTIVE ENERGY USE

## Challenges and Strategies

Natural gas has the potential to become a cost-effective and convenient transportation fuel for select applications if significant market, technical and public policy barriers associated with its use can be overcome. These barriers include the following:

### ➤ Challenge 1: Develop Advanced On-board Fuel Storage Systems

Current on-board fuel tanks impose an unacceptable incremental cost, weight, and space penalty on vehicles. This imposes range limitations and, in some cases, loss of payload capacity which makes natural gas impractical for many applications.

Reducing the weight and volume required for on-board fuel storage will indirectly reduce the marginal cost of cartage (relative to current gas vehicles) and will make natural gas a more cost-effective fuel option.

#### *Strategy*

Conduct research and development on low-cost, safe and lightweight CNG and LNG fuel tanks and on advanced fuel storage media such as adsorbents.

### ➤ Challenge 2: Increase Availability and Convenience of Vehicle Fueling

Natural gas vehicle fueling facilities are not widely available today. In addition, much of the infrastructure in place today is not generally accessible (e.g., because it is on private property). New drivers usually require training to fuel vehicles; fueling facilities use varying procedures and non-standardized fueling connectors or equipment, which can require additional training even for operators familiar with the fuel.

This situation is especially pronounced for liquefied natural gas which, as a cryogenic liquid, requires special handling procedures (e.g., the need to don protective clothing and eye-wear before fueling).

#### *Strategy*

Expand fueling infrastructure and improve performance of existing LNG and CNG refueling stations. Pursue research on such technologies as leakless, freeze-resistant nozzles, odorization of LNG, improved cryogenic pumps and safe breakaway hoses. Also, continue work on broadening LNG supply by supporting R & D on innovative, small-scale liquefaction technologies.

Support research, collaboratively with industry, to cut the cost of an LNG/CNG (bi-fuel) station to be competitive in price to that of conventional fueling stations. Work to reduce the time and cost of getting permits to build and operate such facilities.

EFFICIENT AND PRODUCTIVE ENERGY USE

## Challenges and Strategies (Continued)

### Challenge 3: Integrate Advanced Natural Gas Vehicle Systems Into Practical, Commercial Vehicles

Approximately a decade of Department-sponsored research (on engines, materials, and fuel storage) has been successfully completed. Bringing the results of such R & D together into a system to generate an advanced, yet practical, prototype vehicle in the near-term is the goal of this element of the program.

#### *Strategy*

The Department's NGV program has projects in place to develop a medium-duty (Class 3-6) vehicle fueled with compressed natural gas (CNG) and a heavy-duty (Class 7-8) truck fueled with liquefied natural gas (LNG) with cost and performance comparable to corresponding, conventionally-fueled counterparts. These vehicles will emit regulated pollutants at or below levels of EPA's proposed 2007 standard. Develop prototype vehicles by 2004. The heavy-duty hybrid vehicle program also includes development of a natural gas-fueled prototype.

Develop technologies that address specific technical barriers identified by natural gas heavy vehicle users – for example: accurate and inexpensive fuel gauges and methane detectors. Work with vehicle manufacturers to create fully integrated natural gas vehicles. Support on-road development of vehicles using prototype natural gas engines to identify and resolve remaining weaknesses of prototype engines.

### Challenge 4: Develop Cost-Effective Natural Gas-to-Hydrogen Reforming Technology

Natural gas reforming (to hydrogen), purification, compression and dispensing technologies are too expensive for hydrogen fuel cell vehicle introduction. Payback will not support private-sector investment in fueling infrastructure with current technology.

#### *Strategy*

Develop technologies that will make reforming natural gas to hydrogen at fueling facilities practical and cost-effective; the fueling infrastructure is one component of the research portfolio required to enable the introduction of fuel-cell vehicles.

EFFICIENT AND PRODUCTIVE ENERGY USE

## Challenges and Strategies (Continued)

### Challenge 5: Modify Perception of Natural Gas as a Transportation Fuel

Gaseous fuels in general, and natural gas in particular, are not commonly viewed as transportation fuels by the public or by many commercial fuel users. The perception that natural gas is an exotic vehicle fuel, that it is difficult to fuel natural gas vehicles, and that such vehicles are unsafe and are inherently more expensive is partly due to the relative familiarity of conventional fuels vs. the relative unfamiliarity of natural gas as a vehicle fuel. It is also due to misinformation and, in some cases, to bias against natural gas vehicles based on past experiences with early, poorly-performing, expensive natural gas vehicles.

#### *Strategy*

Identify niche market applications (airports, transit, cargo delivery, etc.) where alternative fuels have the highest probability of commercial success. Work with industry to focus deployment efforts in these critical areas for initial market development.

Through the Clean Cities program, develop grant programs that help to offset the higher first cost of natural gas vehicles and infrastructure equipment during product commercialization phases.

Provide technical problem solving assistance to industry stakeholders that are having difficulty introducing natural gas into their fleet operations.

Provide authoritative and non-biased information related to NGV technologies and product availability. Disseminate this information via public forums, national phone hotline, web sites, and a data collection center.


## Goal: Efficient and Productive Energy Use

### Objective 2: Efficient and Affordable Buildings

**Aim:** To enhance the energy efficiency, affordability, and environmental quality of the Nation's commercial and residential buildings by developing, promoting, and integrating energy-efficient technologies and practices. The overall goal is to avoid primary energy consumption of 5.0 quads in 2020.

**Supports**

| CNES Goal/Objectives | NPC Study Findings |
|---|---|
| • **CNES Goal I, Objective 2** – Significantly increase energy efficiency in the transportation, industrial, and building sectors by 2010.<br><br>The program supports Executive Order 13123,[38] specifically the goals for improved energy efficiency in government buildings, reduced greenhouse gas emissions, and increased use of combined cooling, heat, and power systems and off-grid generation systems, such as fuel cells. | • **Recommendation 3** – Drive research and technology at a rapid rate.... "The government should promote high-efficiency gas technologies, such as fuel cells, gas cooling, and high-efficiency turbines."<br><br>The American Gas Association study[39] recommends balanced energy efficiency and environmental regulation, including codes and standards for buildings and appliances, and Federal R&D funding for distributed generation, fuel cells, and gas cooling. |

America's 104 million households and 4.6 million commercial buildings used 33.5 quads of primary energy in 1999, equal to 36 percent of U.S. primary energy consumption, costing roughly $234 billion.[40] Of this, 8.0 quads were on-site consumption of natural gas, primarily for space heating and water heating. Energy use in buildings contributes 35 percent of U.S. carbon dioxide emissions, 47 percent of sulfur dioxide emissions, and 22 percent of nitrogen oxide emissions.[41] EIA projections indicate that 25 million new households and 19 billion square feet of commercial floor space will be added in the United States by 2020.[42] The specific challenges are:

**Building Cooling, Heating and Power (BCHP) Program**

The development of new "on-site" and "near-site" distributed power generation technologies, such as advanced natural gas microturbines and fuel cells, opens up new possibilities for buildings—the integration of whole-building thermal and electrical energy needs. BCHP has the potential to increase the energy efficiency of buildings by as much as 30 percent, reduce carbon emissions by 45 percent or more, and improve indoor air quality through humidity management. BCHP equipment systems produce both electrical or shaft power and useable thermal energy on-site or near-site, converting as much as 80 percent of the fuel into useable energy.

A part of the Department's Distributed Energy Resources Program, the BCHP Program develops and deploys advanced technologies for energy system integration in residential and commercial buildings, thereby improving the indoor environment, conserving energy resources, and reducing greenhouse gases and other emissions, so that BCHP will be the preferred method of energy utilization in buildings by the year 2020.

EFFICIENT AND PRODUCTIVE ENERGY USE

## Challenges and Strategies

### Challenge 1: Increase the rate of technology innovation in a fragmented and risk-averse industry

R&D expenditures by the construction industry, as a percentage of sales, are an order of magnitude less than the national industry average. The buildings industry encompasses many thousands of different businesses, millions of individual decision makers, and a wide range of structures and components. Product integration is less than optimal, and industry has been slow to develop and adopt new technologies that are more efficient than conventional designs, materials, and methods. Most of the technology base resides in small firms that are not able to undertake the long-term, high-risk R&D required to develop major new technologies on their own. Gas industry support for end-use R&D has declined due to utility restructuring.

#### *Strategy*

Conduct cost-shared research, development, and demonstration of energy-efficient building equipment, materials, and analytic tools. Accelerate the application of new designs, materials, construction techniques, equipment, and operating practices by means of "whole-building" integration. Develop and implement energy-efficient lighting and appliance standards, building codes, and guidelines. Increase a home's energy efficiency by 50 percent over the 1996 Model Energy Code through Building America partnerships. Promote energy-efficient retrofit of existing commercial and institutional buildings (Rebuild America, Energy Smart Schools).

Improve specific building components through R&D, national standards to eliminate the most inefficient items, and promote the most efficient equipment and appliances (Energy Star program with EPA).

### Challenge 2: Cogenerate electric and thermal energy for buildings

The primary energy lost in central-station generation of electricity for buildings is nearly twice the fossil fuel consumed directly at the building site for space heating, water heating, and other thermal energy uses. The buildings sector consumes two-thirds of all electricity generated in the United States, amounting to 7.6 quads of electric energy, as measured at the building site, along with an additional 16.5 quads of electricity-related energy losses.[43]

#### *Strategy*

Conduct cost-shared research, development, and demonstration of components and packaged systems for the production of electrical power, cooling, and heating from a single fuel input, using advanced power generation technologies including fuel cells, gas turbines, and internal combustion engines, together with advanced energy recovery and utilization technologies. Demonstrate successful applications of BCHP systems, initially by combining existing components into integrated systems, and developing information and tools for the analysis and design of BCHP systems. Develop "next-generation BCHP systems" offering "flexible interdependence" with electric and gas utilities. Conduct research and development on heat exchangers to improve economic use of waste heat. Work with building developers and equipment manufacturers to identify and implement community test beds and full-scale demonstrations of BCHP systems.


## Challenges and Strategies (Continued)

### ➤ Challenge 3: Develop fuel cell systems for buildings

The operating conditions for operation of fuel cells in buildings pose stringent performance requirements not found in other applications. Fuel cells operating on natural gas are a key technology for improving building energy efficiency. However, components and subsystems must be developed for economic and reliable operation under the specific conditions required by building applications.

#### *Strategy*

Develop and demonstrate fuel cell components and systems for cogeneration in buildings (proton-exchange membrane (PEM), molten carbonate (MC), solid oxide). Develop advanced technologies for improved natural gas reforming and clean-up of carbon monoxide and for operation at temperatures in excess of 100°C, with thermal-to-electrical energy efficiency at full power of 35 percent or higher, operating pressure of 1.5 atmospheres or lower, simple construction, high reliability during long-term operation (>40,000 hours) on natural gas reformate from low-cost fuel processors, and overall installed system cost target of $1,500/kW or lower for PEM.

For molten carbonate and solid oxide fuel cells (250kW to 1,000kW) targets are: 1) conversion efficiency of 60 percent; 2) single-digit NOx emissions (e.g., less than 1 part per million); 3) fuel cell stack life in excess of 40,000 hours, and 4) initial system market entry cost of $1,000–$1,500 per kilowatt. Develop software for systems analysis and design. Developing codes and standards for system installation and use in buildings.

### ➤ Challenge 4: Improve indoor air quality with minimal energy impact

Stricter indoor air-quality standards require increased ventilation rates in buildings, which in turn require more heating or cooling of outside air. Conventional air conditioners are not designed to handle large outdoor-air ventilation rates or indoor moisture loads and cannot comply with the required minimum ventilation standard without dramatically increasing energy consumption. Desiccant-based systems can reduce humidity efficiently but must overcome problems of initial cost, physical size, and inadequate performance information.

#### *Strategy*

Conduct cost-shared research, development, and demonstration of desiccant technology to be integrated into building air-conditioning systems for humidity control, thereby improving indoor air quality and comfort, while reducing energy consumption. Develop solid and liquid desiccant systems that are directly gas-fired or regenerated with alternative energy sources, such as waste heat from refrigeration processes, solar energy, or BCHP systems. Collaborate with the U.S. Air Quality Consortium to benchmark current performance, develop generic design tools, support technology transfer, develop and demonstrate new hardware, support industry efforts to develop and implement rating and certification methods, and educate industry users.


## Challenges and Strategies (Continued)

### Challenge 5: Develop environmentally friendly air-conditioning systems

Air conditioning is the single leading cause of electric system peak loads. Concerns about stratospheric ozone depletion are requiring the replacement of CFC / HCFC refrigerants used in building air-conditioning systems.

#### *Strategy*

Conduct cost-shared research, development, and demonstration of advanced thermally-activated, absorption-cycle heat pumps using natural gas or thermal energy from cogeneration. Develop and commercialize the Generator Absorber Heat Exchanger (GAX) heat pumps for residential and small commercial buildings, reducing heating energy use by as much as 50 percent while also providing air conditioning. Develop and commercialize the "Hi-Cool" heat pump, with a targeted 30 percent improvement in cooling performance for cooling-dominated markets. Complete testing of the Double Condenser Coupled chiller for near-term commercialization. Develop an air-cooled chiller in the 5- to 200-ton range suitable for the U.S. climate.

### Challenge 6: Improve Federal government's energy efficiency

The largest energy consumer in the world, the U.S. government spends nearly $8 billion annually for its 500,000 buildings, vehicles, and process energy. The Federal government can reduce its energy costs and provide a market to demonstrate the benefits of improved energy efficiency.

From 1980 to 1994, the Federal investment in energy efficiency totaled $3.3 billion, achieving a cumulative savings of $9.8 billion in the nation's energy bill from a 1985 baseline. From now to 2005, the government's goal is to double the rate at which Federal agencies improve energy efficiency, and this means doubling past investments. A lesser effort will fail to achieve the goals of the *Energy Policy Act of 1992 (EPAct)* and *Executive Order 13123*, which call for a 30-percent efficiency improvement by 2005, and a 35-percent efficiency improvement by 2010.

#### *Strategy*

Provide technical, financial, and management assistance to help agencies to increase energy efficiency and reduce energy costs via natural gas technologies *(Federal Energy Management Program).*


## Goal: Efficient and Productive Energy Use

### Objective 3: Clean and Productive Industries

**Aim:** To develop generic precompetitive technologies through cooperative efforts with nine of the major process and extraction industries in the industrial sector to achieve 25-percent reduction in energy consumption per unit output by 2010.

**Supports**

| CNES Goal/Objectives | NPC Study Findings |
|---|---|
| • **CNES Goal I, Objective 2** – Significantly increase energy efficiency in the transportation, industrial, and buildings sector by 2010. | • **Recommendation 3** – Drive research and technology development at a rapid rate.<br>• **Recommendation 6** – Assess the impact of environmental regulation on natural gas supply and demand. |


## Challenges and Strategies

The industrial sector consumed nearly 35 quads of energy in 1997, about 38 percent of all energy used in the United States. More than 80 percent of the energy consumed in manufacturing (including feedstocks) occurred in only seven process industries: Aluminum, steel, metal casting, forest products, glass, chemicals, and petroleum. Mining and agriculture are the major energy users in the extraction industries.[44] An important consideration in the development of industrial technologies is the type of fuel used. A given application may use solid (e.g., coal or biomass), liquid (e.g., oil) or gaseous (e.g., natural gas) fuels. However, because of its inherent simplicity, low environmental impact and ease of delivery, natural gas has emerged as the fuel of choice in many industrial process-heating applications.

Overall, natural gas accounts for approximately one-third of all energy used by industry. This number can be considerably higher where direct heating applications are preferred. As a consequence, natural gas-based technologies play a central role in the Department's industrial R&D program, and are inextricably tied to achieving the goals of the program. Industrial R&D faces inherent challenges. These include a general aversion to risk by industrial companies, and the practice of scheduling of major capital projects to minimize impact on the production. Finally, several of the major industries are facing extremely low, or even negative, profit margins in the face of the recent economic situations in Asia and Eastern Europe.

In recognition of these challenges, the nine major industries named above have joined with the Department to develop Vision Statements and R&D Roadmaps that establish the technology development agendas for the next two decades. The nine roadmaps, along with roadmaps for combustion, process heating, forging, heat treating, welding and advanced materials that cut across industry boundaries, provide the framework for cooperative private/public efforts to address the energy reduction goal.

Development of industrial gas-based technologies faces additional significant challenges beyond those inherent in other industrial R&D. The first two are a function of the fuel itself:

EFFICIENT AND PRODUCTIVE ENERGY USE

# Challenges and Strategies (Continued)

## Challenge 1: Improving the efficiency of natural gas-fired combustion

Despite its clear advantages over other fuels with respect to ease of application and low emissions, natural gas has a major disadvantage with respect to the way it burns. Because natural gas has the highest hydrogen to carbon ratio of any fossil fuel (itself an advantage when CO2 emissions are considered), flue gases typically are approximately one-fifth water vapor. The latent heat represented by the escaping water vapor is difficult to capture, and rarely is recovered in industrial processes. This puts an upper limit on the efficiency possible.

### *Strategy*

Establish cooperative programs to develop technologies that provide cost-effective approaches to improving the efficiency of gas-fired industrial systems. For example, the Packed Media/Transfer Membrane High Efficiency Boiler, funded in the Crosscutting Combustion Program, aims to achieve greater than 94-percent thermal efficiency in part by drying the exhaust gases using an advanced transfer membrane capable of selectively removing water vapor.

## Challenge 2: Enhancing the radiant properties of natural gas flames

The well-known natural gas "blue" flame is not as radiant as the flames from coal or oil, which are more yellow. This limits the radiant heat transfer from natural gas, and makes natural gas less desirable in applications that depend on highly radiant flames to achieve desired productivity or product quality.

### *Strategy*

Establish cooperative programs to develop technologies that enhance the radiant heat transfer properties of natural gas flames. Examples include:

- Oscillating Combustion, funded in the Glass and Steel Industries of the Future programs, uses varying fuel/air mixtures to increase radiant heat transfer to the load.
- Dilute Oxygen Combustion, funded in the Steel Program, uses delayed mixing of the fuel and oxidizer to minimize localized flame fronts with an overall increase in radiant heat transfer.
- The Vertical Flotation Melter, funded in the Aluminum Program, uses an innovative indirect-fired rotating kiln design to achieve more than 75-percent thermal efficiencies.

EFFICIENT AND PRODUCTIVE ENERGY USE

# Challenges and Strategies (Continued)

## Challenge 3: Declining support for industrial RD&D

In the early 1990s the Federal Energy Regulatory Commission began a phase out of tariffs on the interstate transportation of natural gas that supported RD&D. Subsequent changes in the market for natural gas have significantly reduced the availability of funds for development of industrial natural gas technologies. Because industrial users were now permitted to bypass their local gas companies to obtain the lowest price possible, many local gas distributors began to reduce or eliminate support of new industrial technology development. The funds normally applied to the development of gas technologies were diverted to improving the gas distribution systems, operations, and other areas directly relevant to the profitability of the gas company.

### *Strategy*

Coordinate activities of the Federal Government, natural gas companies and industrial users to avoid duplication of effort, in order to maximize the value of each industrial research dollar.

## Challenge 4: Develop new communication linkages

While the success of the activities that involve natural gas utilization has been substantial, the above noted reduction in support for industrial technology development within the natural gas industry must be addressed.

### *Strategy*

Develop new communication linkages with industrial customers. Specific target organizations in addition to the American Gas Association include:

- The Industrial Center, Inc. (a consortium of natural gas companies that supports industrial technology development).
- The Gas Technology Institute (resulting from the merger of the Gas Research Institute and the Institute of Gas Technology).
- The Interstate Natural Gas Association of America (representing the interstate pipelines).
- The Natural Gas Supply Association (comprising the principal suppliers of natural gas).
- The Natural Gas Research, Development and Demonstration Forum, a broad association of gas industry companies with interest in the development of new technologies.
- The individual companies themselves.


# Goal: Energy Information and the Natural Gas Industry

## Objective 1: Comprehensive Natural Gas Information

**Aim:** To provide high-quality data, industry and market analyses, and forecasts.

| Supports |
| --- |
| NPC Study Findings |
| • Collaboration among agencies and industry |

The Department aims to serve public policy makers and decision makers with high quality, timely, and comprehensive natural gas energy information so that the gas industry's performance can be assessed. The development and dissemination of information is conducted by virtually all offices within DOE as part of their core responsibilities, so the responsibility to promote effective information programs involves each DOE program office. However, this role pertains especially to the Energy Information Administration (EIA). This agency was established in 1977 as an independent statistical agency within the U.S. Department of Energy (DOE). EIA was charged by its enabling legislation with maintaining a comprehensive data and information program; developing and maintaining analytical tools and data collection and processing systems; providing analyses that are accurate, timely and objective; and providing information dissemination services. EIA's enabling legislation requires that the agency perform independent analyses.

ENERGY INFORMATION AND THE NATURAL GAS INDUSTRY

# Challenges and Strategies

## Challenge 1: Educating policy decision makers and the public

The contribution that natural gas can make toward achieving national economic, energy and environmental objectives is impeded if information is unavailable or poor quality. DOE should aim to enhance information for stakeholders and communication between stakeholders on natural gas issues to promote and improve effective problem solving. The stakeholders in natural gas issues include a large number of people with diverse perspectives: end-users in homes and businesses; decision makers in local, State and Federal government agencies; owners and neighbors of lands and resources affected by the natural gas supply system; and businesses involved in natural gas supply. Stakeholders need information about price and supply at various points in the gas system and also need more information about the factors affecting the market. Common information needs to be viewed from different perspectives, and information and understanding gaps need to be closed.

Further, government agencies need to understand the interplay between government programs and policies, and the impact that untimely, inconsistent, or duplicative actions can have on the availability of adequate, affordable supplies of natural gas. And, consumers and government agencies need to be confident that appropriate actions will be taken when energy emergencies arise. Using the improved data and independent analyses of EIA as a base, the Department will endeavor to promote a better understanding of natural gas policies and programs through the activities described in this strategy.

### *Strategy*

Improve public understanding of the effectiveness of government's role. Increase public understanding of the role of natural gas in the Nation's energy portfolio.

Enhance communication among Federal, State, and local agencies, tribes, industry, lawmakers and other stakeholders on issues related to natural gas supply and demand, including actions that can be taken to mitigate short-term energy emergencies and to establish a balanced, long-term approach to responsibly developing the Nation's natural gas resource base.

Enhance the capabilities of government agencies to make more cost-effective regulatory and policy decisions affecting natural gas supply and demand and when necessary to reconcile inconsistencies or competing objectives, supporting the White House Interagency Work Group on natural gas as appropriate.

ENERGY INFORMATION AND THE NATURAL GAS INDUSTRY

## Challenges and Strategies (Continued)

### Challenge 2: Improve natural gas data collection, processing, and publication systems to reflect the changes occurring in the gas industry and markets

Regulatory changes have complicated the task of collecting price data about the industry. Most elements of EIA's current natural gas data collection program have been in place for more than 20 years. During this period as the industry has restructured, coverage of certain of its aspects has declined because traditional respondents no longer could provide the information. The most notable change in coverage has occurred as the physical and financial flows of gas in the market place have diverged. EIA's current data collections continue to track the volumes of gas flowing from processing plants and border points of entry through pipelines to storage and end-use customers. However, the coverage of prices has declined as marketers and other new players have entered the industry because they are outside the traditional respondent population. Price coverage already has declined sharply in the industrial sector and significantly in the commercial sector, and coverage of residential prices is in jeopardy as customer choice programs for purchasing natural gas are implemented in several States.

### *Strategy*

EIA will revise its natural gas data system to capture relevant industry and market activities and enhance data collection to maintain comprehensive coverage. The EIA has initiated the *Next Generation * Natural Gas* $(NG)^2$ project to design and implement a new and comprehensive information program for natural gas to meet customer requirements in the post-2000 time frame. EIA will implement revised natural gas surveys incrementally, beginning with completion of a redesigned system for sales to residential and commercial customers in 2001. Data requirements will be coordinated within EIA/DOE, other governmental agencies, and industry working groups. Work with data providers to determine what data items can be collected before completing data requirements.

Develop a plan for new natural gas collection processes to promote timeliness and accuracy, while minimizing respondent burden. As an immediate first step for data collections where non-response is a problem, EIA will implement a policy of expeditiously moving the contact point up both the EIA and respondent management chain. EIA will establish an inter-office team to develop best practices approaches for addressing late response and non-response by February 2001.

ENERGY INFORMATION AND THE NATURAL GAS INDUSTRY

## Challenges and Strategies (Continued)

### ➤ Challenge 3: Enhance access, understandability, and use of natural gas information

The EIA aims to advance the quality and level of access to gas related and other energy information products for use by policy makers, decision makers, industry, and educational institutions. Therefore, our goal to provide a seamless view of EIA to Internet customers who are not and will not need to be familiar with EIA's publications, structure or people to find the information they want. Improved accessability to EIA information products through the Internet is expected to yield benefits to energy markets and the industry by promoting more informed and timely decisions. A wide range of EIA analysis and data publications is currently available to the public; however, EIA hopes to take a proactive approach and provide opportunities to additional analysts and researchers through the technological advancement of the Internet.

### *Strategy*

**Implement an Information Channel Approach on the Website.** EIA has just implemented a new approach on its Website. Each information channel represents an area of interest for a customer and allows that customer to navigate to data, analysis, and forecasts within that area. Examples of information channels are: fuel types, geography, sector, price, process (production, consumption, imports, and other categories) environment, forecasts, and analysis. EIA will constantly monitor customer feedback to ensure that the navigation is seamless across the various EIA products.

**Reaching the Target Audience.** The Internet is a large resource used by millions of people everyday. Despite the widespread access to the Internet, it can still be difficult to reach the most suitable and interested parties for natural gas data and analysis. The following is needed to improve access to EIA information:

1. Links from all applicable channels on the EIA website to the product
2. A request for links from other sites to the product – such as State energy offices, and consumer affairs offices
3. Product advertisement via fliers sent to natural gas distributors, or consumer groups, or subscribers to the natural gas monthly
4. Add and update press releases on the website
5. Make sure that metatags or 'key words' are used and placed properly to help identify appropriate terms
6. Registering the EIA website with the most popular search engines.

**Presenting Data in a Reliable, Readable and Understandable Format.** Every technical website, such as EIA's, has an overabundance of data available to download. Sometimes data may be presented in a manner that is not understandable, not readable, or not clearly labeled for the average consumer. This can pose a problem when expanding the target population for the use of EIA data and analysis products. Data products will be presented in a variety of formats to serve the differing needs of our customers. A PDF format will be presented for those customers who need a formatted publication style. A text or PDF format will be presented for those customers who want to download a data series for further processing. Analysis products will be written in plain language with a minimum of jargon.

**Ensure that Data and Analysis Publications Reach the Appropriate and Most Suitable EIA Customers in the Most Efficient Manner.** As resources have been diminished over the past few years, it has become increasingly important to focus in on certain popular and necessary publications and products. EIA has worked to expand its program of customer notification products. For example, certain products are automatically e-mailed to customers who subscribe when they are created. This notifies the customer that the new information is now available, thus allowing the customer to receive their subscribed product in a more timely and efficient manner. This system has thus far proven to be very popular among our customers.

ENERGY INFORMATION AND THE NATURAL GAS INDUSTRY

## Challenges and Strategies (Continued)

### Challenge 4: Enhance analysis tools to reflect industry and market changes

Structural changes and other industry developments resulting from regulatory changes and new technology have raised the challenge of producing high quality analysis and outlook projections. The advantage of utilizing a comprehensive, integrated modeling system, such as the National Energy Modeling System (NEMS) is maintained by continual adjustments to existing analysis components and incorporating new features as appropriate.

The Department will continually expand and enhance analysis and modeling tools to reflect changes in markets and the industry in an attempt to both improve the quality of the analysis and maintain relevance to key issues of the day.

### *Strategy*

Develop a new world energy modeling system to assess greenhouse gas emission trends. EIA will design, develop, and implement a new world energy modeling system to project and analyze trends in worldwide emissions of greenhouse gases. The new system, based on the MARKAL models already developed in Europe and elsewhere, will include trade flows of oil, natural gas, and coal. Although international flows of natural gas by pipeline and liquefied natural gas tanker are expected to be small, worldwide production and consumption of natural gas are expected to increase significantly, as countries try to reduce or slow the growth of their greenhouse gas emissions. The 15-region model is expected to provide projections every 5 years through 2025.

Enhance analysis tools to reflect industry and market changes. Modify the National Energy Modeling System (NEMS) to reflect major activities in new locations or utilizing new processes. EIA will design, develop, and implement new routines to model natural gas production from the North Slope of Alaska and the conversion of natural gas into synthetic petroleum liquids. Both of these developments are expected to be critical elements affecting the U.S. energy outlook.

Modify the NEMS to reflect structural changes related to restructuring of natural gas and electricity markets. EIA will enhance the NEMS to reflect changes from the traditional highly regulated industry and market structures to a system of increased competition and reduced regulatory involvement by the government. The shift to competition for gas and electricity markets will alter market performance and the long-term trends in both the supply of and demand for natural gas.

# Appendix A.

## Aspects of Uncertainty in the Outlook

To facilitate favorable outcomes, an effective strategic plan should address assumptions and uncertainties in major factors. The EIA long-term outlook shows the projected impact and cost of legislation and environmental regulations that affect producing and consuming sectors. The *Annual Energy Outlook 2001 (AEO2001)* represents current legislation and environmental regulations as of July 1, 2000, and the costs of compliance with other regulations.

The *AEO2001* depends on several key factors, including assumptions and the presumed industry and market behavior. The outlook represents these assumptions by factors that are subject to considerable uncertainty. Some of these values are not external to the system, but depend on activities of the participants. For example, technology is assumed to improve over time with benefits flowing to the industry and consumers. The outlook does not address the mechanism and level of effort needed to achieve the assumed levels, but rather reflects the viewpoint that the future will be consistent with the past and historical trends will continue. For uncertain variables, the AEO2001 used several reference cases.

This appendix presents major assumptions found in the AEO2001. It describes key regulatory, programmatic, and resource assumptions that factor into the projections. More detailed assumptions for each sector are available on the Internet at Web site www.eia.doe.gov/oiaf/aeo/assumption/index.html.

## World Oil Price Assumptions

The world oil price in the present context is defined as the annual average acquisition cost of imported crude oils to U.S. refiners. The reference cases reflect assumptions about the expansion of production capacity in the nations forming the Organization of Petroleum Exporting Countries (OPEC), particularly those producers in the Persian Gulf region. The forecast of the world oil price in a given year is a function of OPEC production capacity utilization and the world oil price in the previous year. The reference case does not assume any disruptions in petroleum supply.

## Electricity Assumptions

The reference case assumes a transition to full competitive pricing in California, New York, New England, the Mid-Atlantic Area Council, and Texas. In addition, electricity prices in the following regions are assumed to be partially competitive:

- East Central Area Reliability Council.
- Mid-America Interconnected Network.
- Rocky Mountain Power Area/Arizona.
- Southwest Power Pool.

Some of the States in each of these regions have not taken action to deregulate their pricing of electricity. In those States prices are assumed to continue to be based on traditional cost-of-service pricing. The reference case assumes price freezes or reductions over a specified transition period when mandated by many of the deregulated states. In general the transition period is assumed to be a 10-year period from the beginning of restructuring in each region, during which prices gradually shift to competitive prices. The transition period reflects the time needed to establish competitive market institutions and recover stranded costs as permitted by regulators. The reference case assumes that the competitive price in these regions will be the marginal cost of generation.

## Oil and Gas Supply Assumptions

*Domestic oil and gas technically recoverable resources*. The assumed resource levels are based on estimates of the technically recoverable resource base. The estimates are from the U.S. Geological Survey (USGS) and the Minerals Management Service (MMS) of the Department of the Interior, with supplemental adjustments to the USGS non-conventional resources by Advanced Resources International [(ARI), an independent consulting firm]. Resources for the Gulf of Mexico were also adjusted on the basis of estimates from a December 1999 report by the NPC.[45]

*Technological improvements affecting recovery and costs*. Productivity improvements are simulated by assuming that drilling, success rates, and finding rates will improve and the effective cost of supply activities will be reduced. The increase in recovery is due to the development and deployment of new technologies, such as three-dimensional seismology and horizontal drilling and completion techniques. Drilling, operating, and lease equipment costs are expected to decline because of technological progress, at econometrically estimated rates that vary somewhat by cost and fuel categories, ranging roughly from 0.5 percent to 2.0 percent. These technological impacts work against increases in costs associated with drilling to greater depths, higher drilling activity levels and rig availability. Because of progress in technology, exploratory success rates are assumed to improve by 6.7 to 8.5 percent per year, and finding rates are expected to improve by 4.2 to 6.9 percent per year.

*Leasing and drilling restrictions*. The projections of crude oil and natural gas supply assume that current restrictions on leasing and drilling will continue to be enforced throughout the forecast period. At present, drilling is prohibited along the entire East Coast, the west coast of Florida, and the West Coast except for the area off Southern California. In Alaska, drilling is prohibited in a number of areas, including the Arctic National Wildlife Refuge. The projections also assume that coastal drilling activities will be reduced in response to the restrictions of CAAA90: With the exception of areas off Texas, Louisiana, Mississippi, and Alabama, offshore drilling sites within 25 miles of the coast must meet the same clean air requirements as onshore drilling sites.

*Gas supply from Alaska and LNG imports.* The Alaska Natural Gas Transportation System is assumed to come on line no earlier than 2009 and only after the U.S.-Canada border price reaches $3.99, in 1999 dollars per thousand cubic feet. The liquefied natural gas (LNG) facilities at Everett, Massachusetts, and Lake Charles, Louisiana (the only ones currently in operation), have a combined operating capacity of 359 billion cubic feet per year, including a 1999 expansion of 48 billion cubic feet in the Massachusetts facility. The facilities at Elba Island, Georgia, and Cove Point, Maryland, are assumed to reopen in 2003. Should these facilities reopen, total LNG operating capacity would increase to 840 billion cubic feet per year.

*Natural gas transmission and distribution assumptions.* Transportation rates for pipeline services are calculated with the assumption that the costs of new pipeline capacity will be rolled into the existing rate base. The rates based on cost of service are adjusted according to pipeline utilization, to reflect a more market-based approach.

In determining interstate pipeline tariffs, the AEO does not consider capital expenditures for refurbishment over and above that included in operations and maintenance costs or potential future expenditures for pipeline safety. (Refurbishment costs include any expenditures for repair or replacement of existing pipe.) Distribution markups to core customers (not including electricity generators) change over the forecast in response to changes in consumption levels and in the costs of capital and labor.

The natural gas vehicle (NGV) sector is divided into fleet and non-fleet vehicles. The distributor tariffs for natural gas to fleet vehicles are based on historical differences between end-use and citygate prices from EIA's Natural Gas Annual plus Federal and State NGV taxes. The price to non-fleet vehicles is based on the industrial sector firm price plus an assumed $3 (1987 dollars) dispensing charge plus taxes. Federal taxes are set and held at $0.49 in nominal dollars per thousand cubic feet.

Initiatives to increase the natural gas share of total energy use through Federal regulatory reform are reflected in the methodology for the pricing of pipeline services. Initiatives to expand the Natural Gas Star program are assumed to recover 35 billion cubic

feet of natural gas (per year from 2000 through the end of the forecast period) that otherwise might be lost to fugitive emissions.

## Macroeconomic Assumptions

The output of the Nation's economy, measured by gross domestic product (GDP), is projected to increase by 3.0 percent a year between 1999 and 2020 (with GDP based on 1996 chain-weighted dollars), higher than the 2.1-percent growth projected in AEO2000 for the same period. The projected growth rate for productivity growth (GDP growth minus labor force growth) is 2.1 percent a year.

The projected rate of growth in GDP slows in the latter half of the forecast period as the expansion of the labor force slows, but sustained levels of labor productivity growth moderate the effects of lower labor force growth. Total population growth remains fairly constant after 2000; the slowing growth in the size of the labor force results instead from the increasing size of the population over 65 years old after 2000. As more people retire from the work force, and as life expectancy rises, the labor force participation rate—the percentage of the population over 16 years of age actually holding or looking for employment—peaks in 2011 and then begins to decline as "baby boom" cohorts begin to retire. Thus, from 2010 to 2015, labor force growth slows to 0.8 percent, and from 2015 to 2020 it falls to 0.6 percent a year. Labor force productivity growth, however, remains near 2 percent a year throughout each of the 5-year periods.

The projected growth rate for manufacturing production is 2.8 percent a year, slightly lower than the 3.0-percent annual growth projected for the aggregate economy. Energy-intensive manufacturing sectors are projected to grow more slowly than non-energy-intensive manufacturing sectors (1.2 percent and 3.3 percent annual growth, respectively), due in part to rising real energy prices.

The electronic equipment and industrial machinery sectors lead the expected growth in manufacturing, as semiconductors and computers find broader applications. The rubber and miscellaneous plastic products sector is expected to grow faster

than manufacturing as a whole, with plastics continuing to penetrate new markets as well. Higher growth is expected for the services sector than for the manufacturing sector, as in last year's forecast.

# Appendix B. R&D Programs

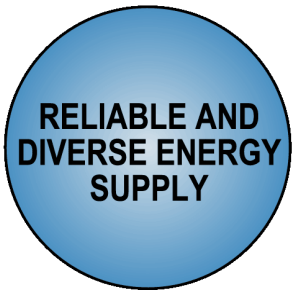
This appendix summarizes DOE's programs for natural gas R&D.

## Reliable and Diverse Energy Supply

### Objective 1: Enhancing Domestic Supplies

***Oil and Gas Exploration and Production.*** To maintain or reduce gas prices while sustaining high production rates, DOE supports R&D to reduce drilling costs, enhance production efficiency, and improve deliverability of the nation's gas storage system. To exploit the U.S."unconventional" resource base, DOE supports mid-term R&D to assess distribution and potential; dramatically reduce costs and risks of deep drilling; improve "sweet-spot" detection in low-permeability reservoirs through advanced exploration technologies; and improve the economics of marginal products. DOE's long-term R&D will extend the life of the current suite of producing resources and enable gas hydrate production.

***Oil and Gas Processing.*** Using new technologies, the oil and gas industry can prevent pollution and protect the environment more efficiently, handle challenges posed by lower quality domestic feedstocks, and produce more complex, purer, high-value product slates. By gathering the scientific information needed for regulatory decision making and by developing efficient, cost-effective, environmentally sound processing technologies, the industry may continue to be profitable in a highly global marketplace.




**Research Programs:**

- Diagnostics and Imaging
- Drilling Completion and Stimulation
- Reservoir Life Extension
- Drilling and Production Environmental Management
- Gas Hydrates

**Research Programs:**

- Low-Quality Gas Upgrading
- Oil Processing and Environmental Protection

RELIABLE AND DIVERSE ENERGY SUPPLY

**Research Programs:**

- Ceramic Membrane Reactor Systems for the Conversion of Natural Gas to Syngas
- Thermoacoustic Natural Gas Liquefaction
- Novel Conversion and Syngas Processes

## Objective 2: Producing Clean Fuels

***Natural Gas-to-Liquids.*** GTL R&D is focusing on several key technical areas, the most prominent being advanced Fischer-Tropsch (F-T) conversion technology. F-T usually involves two major processing steps: generation of an intermediate process gas ("syngas") composed of hydrogen and carbon monoxide, and synthesis of the intermediate gas with a special catalyst to a hydrocarbon liquid, which also can be followed by separate steps of catalyst/liquid separation and liquid finishing to exact product specification. The major capital plant investment required is for the first step of syngas generation, and this is where DOE's research emphasis is currently placed. At the same time, technology advances are being sought for the second step conversion of the syngas to paraffin hydrocarbon liquids, chiefly in the diesel fuel range. Other DOE work addresses the problem of unmarketable natural gas through development of physical liquefaction technology that is economic at smaller-scale than typical giant Liquified Natural Gas (LNG) trains of today, handling upwards of 500 mmcfd of natural gas.

By furthering the advancement and validation of economical Gas to Liquids (GTL) conversion processes, the Federal program can serve not only as a technical facilitator for the public-private Alaskan decision making needed to utilize our large Alaskan gas resources, but one exceedingly helpful in opening up a significant supply of highly desirable, clean-burning liquid transportation fuels.

***Ultra-Clean Transportation Fuels Initiative (UCTFI).*** In the nearer term, ultra-clean transportation fuels can be produced from improved or new refinery upgrading technology. In the mid-to-longer term, ultra-clean transportation fuels from natural gas would enjoy a high level of compatibility with the existing infrastructure, and could provide environmental benefits due to their suitability for use in advanced, high-efficiency vehicle engines. In order to fulfil this role in the most efficient and cost-effective manner, those fossil fuels-related activities that have clean fuels development as their goal have been integrated, along with new activities, into a comprehensive UCTFI for producing fuels for ultra-low emission vehicles. These activities

reside in the Petroleum Program within the Office of Fossil Energy. It has near, mid and long-term goals and is supported by tenants of the Natural Gas-to-Liquids efforts. The initiative seeks to mobilize industrial and National Laboratory capabilities in the development and demonstration of technology for making ultra clean, high-performance motor fuels in large volumes from our diverse fossil energy resource base.

The initiative will have two components: the first component is a solicitation directed toward systems-oriented R&D projects that lead to the production of sufficient quantities of fuel to validate performance and emissions—testing that will be done in collaboration with DOE's Office of Transportation Technologies. The second component is a supporting research program carried out by National Laboratories and co-sponsored with the fuel industry that is focused on the development of advanced fuel-making process components, materials, and chemistry needed for the manufacture of ultra-clean performing transportation fuels.

***Hydrogen Systems.*** The Hydrogen Program has four strategies: 1) expand the use of hydrogen in the near-term by working with industry, including hydrogen producers, to improve the efficiency, lower the emissions, and lower the cost of technologies that produce hydrogen from hydrocarbons and to introduce renewable-based production options; 2) work with fuel cell manufacturers to develop hydrogen-based electricity storage and generation systems that will enhance the introduction and penetration of distributed, renewable-based utility systems; 3) coordinate with the Department of Defense and the DOE's Office of Transportation Technologies to demonstrate safe and cost-effective fueling systems for hydrogen vehicles in urban non-attainment areas and to provide onboard hydrogen storage systems; and 4) work with the National Laboratories to lower the cost of technologies that produce hydrogen directly from sunlight and water. Concerning transportation applications, the Federal role concentrates on the hydrogen refueling infrastructure, onboard vehicle storage of hydrogen, and the cost effectiveness of the hydrogen fuel. On the utility side, a key program need is the demonstration of integrated renewable and hydrogen systems to provide increased operational and peaking generation flexibility.

**Research Programs:**

- Hydrogen Production
- Hydrogen Storage and Use
- Technology Validation
- Analysis and Outreach

CLEAN AND AFFORDABLE POWER

## Clean and Affordable Power

### Objective 1: Advanced Power Systems

**Research Programs:**

- Advanced Gas Turbine Systems
- Advanced Large-Scale Fuel Cell Power Systems
- Carbon Sequestration

***Large High-Efficiency Systems.*** The Department invests in the development of several large, high-efficiency systems, including natural gas power generation technologies and systems. For natural gas systems, a program called "Vision 21" aims for the upper end of performance efficiencies, 60 percent to over 70 percent, at near zero emissions. It features the capability of power generation systems to have fuel flexibility while generating a variety of energy products along with low-cost electricity. Due to the inherent fuel flexibility of gasification combustion systems, they may be synergistically integrated into industrial processes (e.g., refineries, paper mills, food processing plants), delivering even greater economic and environmental benefit by converting process waste to electricity, steam, and chemical products as needed.

The resulting fleet of large, high-efficiency power systems included in Vision 21 would have emissions well below the New Source Performance Standards (NSPS) for SO2, NOx, and particulates, with the most advanced systems achieving near zero emissions of regulated pollutants.

**Research Programs:**

- Industrial Combined Heat and Power Systems
- BCHP Systems
- Advanced Industrial Turbine Systems
- Hydrogen Fuel Cell
- Reciprocating Engines

***Distributed and Hybrid Energy Systems.*** The Department is developing a suite of distributed and hybrid power systems to significantly contribute toward the goal of providing reliable and affordable power generated in an environmentally benign manner. Technologies being developed include the area of co-generation, both Industrial Combined Heat and Power (ICHP) and Buildings Cooling Heating and Power (BCHP), with smaller fuel cells (25–50kW), and small gas turbines and reciprocating engines. Emerging technologies in the BCHP programs will significantly contribute to electric peak shaving during the cooling season, when cooling energy is dominant, in buildings comfort conditioning using desiccant systems, and gas heat pumps and chillers.

## Objective 2: Enhancing Utility Infrastructure

CLEAN AND AFFORDABLE POWER

***Distributed Power.*** Working with its industry and state and local government partners, the Distributed Power program will conduct R&D to address the technical, institutional, regulatory, and financial issues that are critical to realizing the full potential of the use of distributed generation, energy storage, and demand-side management on the power distribution system. The Distributed Power Program focuses on system integration and crosscutting issues that impact several or all distributed power technologies relative to their deployment in the power system, and realization of their full market potential.

**Research Programs:**

- Strategic Research
- System Integration
- Regulatory and Institutional Issues

***Natural Gas Infrastructure.*** The Natural Gas Infrastructure program includes the Gas Storage Technology program initiated in 1993 and a new program for FY 2001—Enhancing Infrastructure Reliability. These programs support DOE's activities and goals to enhance the reliability of existing and new pipeline infrastructure and to remediate greenhouse gas emissions in the gas industry. DOE is working with industry to ensure that the gas delivery and storage system continues to provide a reliable, cost-effective supply of natural gas well into the next century.

**Research Programs:**

- Gas Storage Technology
- Enhancing Pipeline System Reliability

***Secure Energy Infrastructures.*** The nation's energy infrastructure, which is composed of industries that produce and distribute electric power, oil, and natural gas, is susceptible to threats from natural, accidental, and intentional sources. The threats are directed at both physical and cyber assets of the energy sector. The Secure Energy Infrastructure program will collaborate with industry, academia, and other Federal agencies to conduct research that will enhance the protection of the nation's energy infrastructure from disruptions, the mitigation of potential disruptions that do take place, the response to potential disruptions, and the restoration the energy infrastructure to normal operation following a disruption.

**Research Programs:**

- Analysis and Risk Management
- Protection and Mitigation Technologies

EFFICIENT AND PRODUCTIVE ENERGY USE

**Research Programs:**

- Engine Efficiency
- On-board Fuel Storage Systems
- Fueling Infrastructure

# Efficient and Productive Energy Use

## Objective 1: Clean and Efficient Vehicles

***Natural Gas Vehicles.*** Natural gas has the potential to become a cost effective and convenient transportation fuel. Natural gas engines, because of their demonstrated low PM and NOx, are particularly attractive for urban delivery vehicles in class 3-6 trucks. These vehicles provide an excellent application for natural gas since most are operated as fleets with central refueling. Natural gas engines in class 3-6 need significant improvements in part-load efficiency since they normally operate with a lighter load factor than larger highway trucks. Urban delivery vehicles are prime targets for hybrid vehicle technology with the potential for up to 3 times today's fuel economy. Hybrid vehicles, for lowest emissions, will need a natural gas engine designed especially for the hybrid system.

The program strategy includes research and development of natural gas storage to complement these engines. One specific project focuses on the development of onboard high-pressure fuel delivery systems for direct natural gas fuel injectors. Other projects include testing of conformable tanks, developing smart tank technologies, developing low-pressure storage, studies on natural gas storage for heavy vehicle market penetration, and demonstrating the advantages of LNG/CNG refueling. Performance measures for this activity are developing safe, reliable, cost-efficient components for heavy vehicle fuels storage.

## Objective 2: Efficient and Affordable Buildings

**Research Programs:**

- Absorption Technologies
- Desiccants

***Heating, Cooling and Air Conditioning.*** A variety of equipment provides space conditioning services, including heat pumps, furnaces and boilers, chillers, and others. Thermal distribution systems include fans, ducting, piping, heat exchangers, and controls and can also be the means of primary ventilation. More highly advanced systems incorporate computers, sophisticated building sensors, and complex control strategies.

The equipment used in a given building is determined by building size, function, geographic region, availability of fuel types, consumer preferences, and other factors. Opportunities for the most cost-effective energy savings and improved performance in a given application vary by technology. For example, a natural gas-fired absorption heat pump has the potential to have substantially lower (40 to 50 percent) operating costs compared to conventional heating and cooling systems and also offers an opportunity to serve cooling needs with natural gas. Desiccant systems offer energy and cost savings (as well as precise humidity control and alleviation of moisture-related indoor air problems).

***Building Materials and Envelope.*** The Department's research activities center on both building design and construction, as well as operation and maintenance (O&M). During building design and construction, subsystem, and component choices are made and actual construction begins. During the O&M phase, the building is occupied and in use. DOE develops tools and protocols for building design and operation as well as providing the technical basis for the industry consensus process for standards and guidelines, such as those of ASHRAE and ASTM.

**Research Programs:**

- Commercial Buildings
- Residential Buildings

***Appliances.*** Appliances provide a variety of energy services, including water heating, food preparation and storage, clothes washing and drying, dish washing, and other services ranging from entertainment to security. Water heating is the third largest end use for buildings in terms of magnitude, consuming about 3.9 quadrillion Btu in 1996 (11.3 percent of total buildings energy use), at a consumer cost of $25.9 billion. Refrigeration/freezers are also large energy users, about 2.2 quadrillion Btu in 1996 (6.4 percent of total buildings energy use) at a cost of $16.3 billion. Improved technologies under development include heat pump water heaters, improved insulations for refrigerators, and "integrated" appliances where, for example, waste heat from one serves as a heat source for another.

**Research Programs:**

- Refrigeration
- Heat Pump and Water Heater Appliances

***On-Site Generation.*** On-site power plants can range in size from a few watts to several hundred kilowatts. Potential "distributed" generation technologies include fuel cells, photovoltaics, micro turbines, and reciprocating, and rotary engines. The Department's buildings research in this area is currently focused on fuel cells.

**Research Programs:**

- Fuel Cells

EFFICIENT AND PRODUCTIVE ENERGY USE

**Research Programs:**

- Aluminum
- Steel
- Metal Casting
- Glass

## Objective 3: Clean and Productive Industries

***Industries of the Future.*** Research and development, along with testing, demonstration, and evaluation programs, are undertaken on a broad array of technologies that are identified by the Industries of the Future as priorities in their technology roadmaps and that meet the Department's missions and goals. Individual projects range across the spectrum from small focused research tasks and activities of relatively short duration, to multi-year, major technology development projects. Research projects may focus on individual technical disciplines or on multi-disciplinary areas. The characteristics and needs of each industry vary, and determine the nature and balance of the activities in the individual portfolios.

Because of its inherent simplicity, low environmental impact, and ease of delivery, natural gas has emerged as the fuel of choice in many industrial process-heating applications. Overall, natural gas accounts for approximately one-third of all energy used by industry. This number can be considerably higher where direct heating applications are preferred. As a consequence, natural gas-based technologies play a central role in the Department's industrial R&D strategy, and are inextricably tied to achieving the goals of the program.

# Appendix C. Roadmap

## Roadmap for Reliable and Diverse Energy Supply

RELIABLE AND DIVERSE ENERGY SUPPLY

| | Enhancing Domestic Supplies | Producing Clean Fuels |
|---|---|---|
| 2001 | • Initiate stripper well consortium. | • Begin operation of nominal 24 million standard cubic feet per day (MSCFD) Ionic Transport Membrane (ITM) Syngas Process Development Unit (one barrel per day equivalent). |
| 2002 | • Initiate new technology program for Offshore Gulf of Mexico for both ultra deepwater and deep formations in shallower water. | • Complete technical feasibility assessment of transporting Gas-to-Liquids (GTL) products through the Trans Alaska Pipeline System. |
| 2003 | • Complete development and testing of technologies for Rocky Mountain tight gas. | • Complete initial testing of prototype Catalytic Hot Oxygen Reactor and begin operation of 500 MSCFD ITM Syngas Sub-Scale Engineering Prototype Unit. |
| 2004 | • Achieve interagency consensus, based on DOE research, on a modeling system of the impacts of natural gas E&P activities on air quality in the Rocky Mountain region. | • Complete design for integrated prototype Fischer-Tropsch conversion unit for Alaskan or off-shore site and the development of small modularized Fischer-Tropsch plants.<br>• Complete development of the Oxygen Transport Membrane (OTM) Technology as well as the assessment of gas reforming technology and oxygenate synthesis as processing components of a Fischer-Tropsch facility.<br>• Complete characterization of GTL products and associated fleet tests of the GTL fuels.<br>• Complete engineering and economic studies of fuel cell transportation fleets fueled with natural gas-derived methanol. |
| 2005 | • Define potential hydrate production technology. | • Complete construction for integrated prototype Fischer-Tropsch conversion unit in Alaska or at an off-shore site that also includes slip-stream testing capability for further advances in conversion technology (e.g., the newly designed integrated prototype ceramic transport reactor/synthesis gas conversion unit). |

## Clean and Affordable Power

CLEAN AND AFFORDABLE POWER

| | Advanced Power Systems | Enhancing Utility Infrastructure |
|---|---|---|
| 2001 | • Complete 4,000 hrs. of testing of the first industrial-scale (4.3 MW) Advanced Turbine Systems (ATS).<br>• Initiate testing of the first hybrid solid oxide fuel cell/gas turbine system (220 kW).<br>• Verify zero emissions power plant gas generator concept operation. | • Field test energy/gas flow meter leading to the commercialization by industry by 2004. |
| 2002 | • Demonstrate the first commercial-scale 300kW to 1MW molten carbonate fuel cell system.<br>• Complete sub-component testing for an advanced low emission system for advanced gas turbines.<br>• Initiate an advanced thermal barrier coating long-tem durability test for gas turbines. | • Demonstrate commercial viability of sonic tool for storage well deliverability enhancement.<br>• Complete technical review of gas storage in lined rock cavern research. |
| 2003 | • Test a 1MW pressurized solid oxide fuel cell/gas turbine system.<br>• Initiate a long-term 4,000-hour advanced microturbine test with ceramic components.<br>• Complete development of first generation sensors/controls/diagnostic technologies for RAM improvement system platforms. | • Complete technical assessment of novel in-line inspection devices to measure pipe integrity.<br>• Demonstrate a design criteria for salt caverns with the goal of reducing minimum allowable gas pressures to increase working gas volume.<br>• Complete field test of a third party damage inspection device. |
| 2004 | • Achieve private sector investment in fuel cell technology for commercial manufacturing of 400 MW per year fuel cell systems.<br>• Complete validation testing and component development of next generation turbine systems.<br>• Conduct a 12 MW zero emission power plant field test.<br>• Demonstrate a high temperature PEM fuel cell with Combined Heat and Power. | • Complete field test of remote and mobile real-time leak technologies. |
| 2005 | • Field test the first 5kW fuel cell using solid state composition developed under the Solid State Energy Conservation Alliance (SECA).<br>• Complete full scale test of a next generation turbine system (NGT) over 30 MW.<br>• Demonstrate a RAM improvement information technology (IT) system at a U.S. turbine power plant complex.<br>• Demonstrate a 40 MW Ramgen engine at a host site.<br>• Demonstrate an advanced microturbine with 40% efficiency. | • Demonstrate the technical and economical feasibility of storing natural gas as hydrates. |

## Efficient and Productive Energy Use

EFFICIENT AND PRODUCTIVE ENERGY USE

| | Clean and Efficient Vehicles | Efficient and Affordable Buildings | Clean and Productive Industries |
|---|---|---|---|
| 2001 | • Select CNG & LNG platforms with vehicle working group.<br>• Build two prototype low-cost fueling facilities in California.<br>• Test low-pressure, adsorbent-based natural gas storage system. | • Complete commercial-scale testing of highly efficient triple-effect gas-fired chiller for large buildings. | • Demonstrate Methane De-Nox technology at two additional industrial facilities.<br>• Host site facility preparation and installation of full-size Vertical Flotation Melter. |
| 2002 | • Prepare specifications for prototype CNG vehicle RFP.<br>• LNG & CNG station capital cost less than $250k.<br>• Develop full-scale adsorbent with storage density of CNG tanks. | • Complete development and testing of small- to medium-sized air cooled commercial chiller using waste heat or natural gas firing. | • Demonstrate full size Vertical Flotation Melter at host commercial site, followed by data reduction and analysis.<br>• Commercial system design of an advanced, high efficiency, low emission petroleum refinery heater. |
| 2003 | • Complete design & initiate development of CNG & LNG prototypes.<br>• Liquefaction capital cost $50 per gallon per day.<br>• Attain capital cost of $96/diesel gallon equivalent for LNG tank. | • Complete development and testing of the gas-fired Generator Absorber Heat Exchanger (GAX) family of residential heat pumps. | • Complete laboratory development and testing of ultra-high efficiency, low emissions industrial boiler design. |
| 2004 | • Place CNG & LNG prototypes on road for final development. | • Demonstrate modularized, integrated “certified building” cooling, heating, and power packaged systems. | • Demonstrate prototype of ultra-high efficiency, low emissions industrial boiler design. |
| 2005 | • Introduce CNG & LNG concept vehicles into at least three fleets each.<br>• Liquefaction capital equipment cost $40 per gallon per day.<br>• Attain capital cost of $70/diesel gallon equivalent for LNG tank.<br>• Off-board reformation of natural gas to hydrogen cost-competitive with conventional fuels. | • Demonstrate building cogeneration system (50-300 kW) based on high-temperature proton-exchange membrane (PEM) fuel cell. | • Demonstrate advanced, high efficiency, low emission petroleum refinery heater integrated system demonstration. |

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# Appendix D. Budget

## DOE Natural Gas Crosscutting Budget for FY99-01
## Includes the Gas Technologies Institute's (GTI's) 2001 Budget for Reference

| Program | Department-Wide | | | GTI | Fossil Energy | | | Energy Efficiency | | | Science | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY1999 | FY2000 | FY2001 | FY2001 | FY1999 | FY 2000 | FY2001 | FY1999 | FY2000 | FY2001 | FY1999 | FY2000 | FY 2001 |
| **I. Reliable and Diverse Energy Supply** | | | | | | | | | | | | | |
| **a. Enhancing Domestic Supplies** | | | | | | | | | | | | | |
| Exploration and Production | 19,400 | 17,300 | 15,800 | 11,420 | 12,900 | 14,300 | 14,300 | | | | 6,500 | 3,000 | 1,500 |
| Gas Hydrates | 500 | 3,000 | 10,000 | | 500 | 3,000 | 10,000 | | | | | | |
| Environmental | 3,000 | 3,200 | 2,600 | 4,950 | 3,000 | 3,200 | 2,600 | | | | | | |
| Coal Mine Methane | 0 | 0 | 1,900 | | | | 1,900 | | | | | | |
| **Total Supply Budget** | **22,900** | **23,500** | **30,300** | **16,370** | **16,400** | **20,500** | **28,800** | | | | **6,500** | **3,000** | **1,500** |
| **b. Producing Clean Fuels** | | | | | | | | | | | | | |
| Gas-to-Liquids | 6,900 | 6,400 | 6,300 | | 6,900 | 6,400 | 6,300 | | | | | | |
| Low-Quality Gas Upgrading | 1,900 | 3,500 | 1,600 | 2,330 | 1,900 | 3,500 | 1,600 | | | | | | |
| Hydrogen | 3,000 | 6,200 | 7,000 | | | | | 3,000 | 6,200 | 7,000 | | | |
| **Total Fuels Budget** | **9,900** | **16,100** | **14,900** | **2,330** | **8,800** | **9,900** | **7,900** | **3,000** | **6,200** | **7,000** | | | |
| **Reliable and Diverse Energy Supply Budget** | **32,800** | **39,600** | **45,200** | **18,700** | **25,200** | **30,400** | **36,700** | **3,000** | **6,200** | **7,000** | **6,500** | **3,000** | **1,500** |
| **II. Clean and Affordable Power** | | | | | | | | | | | | | |
| **a. Advanced Power Systems** | | | | | | | | | | | | | |
| Turbines | 97,500 | 76,500 | 38,800 | | 44,500 | 44,200 | 29,000 | 53,000 | 32,300 | 9,800 | | | |
| Fuel Cells | 45,950 | 48,050 | 58,000 | 1,050 | 44,200 | 44,500 | 52,700 | 1,750 | 3,550 | 5,300 | | | |
| Microturbines | 0 | 0 | 10,000 | | | | | | | 10,000 | | | |
| Reciprocating Engines | 0 | 0 | 3,000 | | | | | | | 3,000 | | | |
| Building, Cooling, Heat and Power | 8,390 | 10,405 | 15,600 | | | | | 8,390 | 10,405 | 15,600 | | | |
| Crosscutting DER | 500 | 1,700 | 2,000 | 1,980 | | | | 500 | 1,700 | 2,000 | | | |
| Other | 0 | 1,340 | 2,000 | 4,400 | | | | | 1,340 | 2,000 | | | |
| **Total Power Budget** | **152,340** | **137,995** | **129,400** | **7,430** | **88,700** | **88,700** | **81,700** | **63,640** | **49,295** | **47,700** | | | |
| **b. Enhancing Energy Systems Reliability** | | | | | | | | | | | | | |
| Infrastructure | 1,000 | 1,000 | 4,900 | 33,090 | 1,000 | 1,000 | 4,900 | | | | | | |
| Storage | 0 | 0 | 3,200 | 1,270 | 0 | 0 | 3,200 | | | | | | |
| **Total Reliability Budget** | **1,000** | **1,000** | **8,100** | **34,360** | **1,000** | **1,000** | **8,100** | | | | | | |
| **Clean and Affordable Power Budget** | **153,340** | **138,995** | **137,500** | **41,790** | **89,700** | **89,700** | **89,800** | **63,640** | **49,295** | **47,700** | | | |

## DOE Natural Gas Crosscutting Budget for FY99-01
## Includes the Gas Technologies Institute's (GTI's) 2001 Budget for Reference

| Program | Department-Wide | | | GTI | Fossil Energy | | | Energy Efficiency | | | Science | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY 1999 | FY2000 | FY2001 | FY2001 | FY1999 | FY 2000 | FY2001 | FY1999 | FY2000 | FY2001 | FY1999 | FY2000 | FY 2001 |
| **III. Efficient and Productive Energy Use** | | | | | | | | | | | | | |
| **a. Clean and Efficient Vehicles** | | | | | | | | | | | | | |
| Natural Gas Vehicles | 17,170 | 21,150 | 22,180 | | | | | 17,170 | 21,150 | 22,180 | | | |
| Natural Gas for Fuel Cells | 6,800 | 7,400 | 8,300 | | | | | 6,800 | 7,400 | 8,300 | | | |
| Materials Technologies | 4,500 | 4,340 | 3,750 | | | | | 4,500 | 4,340 | 3,750 | | | |
| **Total Vehicles Budget** | **28,470** | **32,890** | **34,230** | **0** | | | | **28,470** | **32,890** | **34,230** | | | |
| **b. Efficient and Affordable Buildings** | | | | | | | | | | | | | |
| Technology Roadmaps and Competitive R&D | 2,243 | 709 | 0 | | | | | 2,243 | 709 | 0 | | | |
| Equipment, Materials, and Tools | 0 | 0 | 0 | 7,240 | | | | 0 | 0 | 0 | | | |
| **Total Buildings Budget** | **2,243** | **709** | **0** | **7,240** | | | | **2,243** | **709** | **0** | | | |
| **c. Clean and Productive Industries** | | | | | | | | | | | | | |
| Industries of the Future/ Combustion Systems | 11,592 | 8,562 | 9,314 | 2,270 | | | | 7,792 | 5,062 | 5,814 | 3,800 | 3,500 | 3,500 |
| Materials | 7,200 | 9,000 | 9,000 | | | | | 7,200 | 9,000 | 9,000 | | | |
| Best Practices/ Supporting Industries | 0 | 0 | 3,100 | | | | | 0 | 0 | 3,100 | | | |
| **Total Industries Budget** | **18,792** | **17,562** | **21,414** | **2,270** | | | | **14,992** | **14,062** | **17,914** | **3,800** | **3,500** | **3,500** |
| **Efficient and Productive Energy Use** | **49,505** | **51,161** | **55,644** | **9,510** | | | | **45,705** | **47,661** | **52,144** | **3,800** | **3,500** | **3,500** |
| **Total Natural Gas Budget** | **235,645** | **229,756** | **238,344** | **70,000** | **114,900** | **120,100** | **126,500** | **112,345** | **103,156** | **106,844** | **10,300** | **6,500** | **5,000** |

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# Appendix F. Glossary

The source for these definitions is the DOE Energy Efficiency and Renewable Energy Network: http://www.eren.doe.gov/consumerinfo/glossary.html.

## Glossary Terms

**alternate fuels** — A popular term for "non-conventional" transportation fuels derived from natural gas (propane, compressed natural gas, methanol, etc.) or biomass materials (ethanol, methanol).

**biomass fuels** — As defined by the Energy Security Act (PL 96-294) of 1980, "any organic matter which is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants."

**Btu** — British Thermal Unit – The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories.

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| **cogenerators** | A class of energy producer that produces both heat and electricity from a single fuel. |
| **combined-cycle facility** | A power plant that uses two thermodynamic cycles to achieve higher overall system efficiency; e.g., the heat from a gas-fired combustion turbine is used to generate steam for heating or to operate a steam turbine to generate additional electricity. |
| **commercial sector** | Businesses that are not engaged in transportation or manufacturing or other types of industrial activities. |
| **combustion turbine** | A turbine that generates power from the combustion of a fuel. |
| **Decentralized (Energy) System** | Energy systems supply individual, or small groups, of energy loads. |
| **deregulation** | The process of changing regulatory policies and laws to increase competition among suppliers of commodities and service. The process of deregulating the electric power industry was initiated by the Energy Policy Act of 1992. (See also Restructuring) |
| **distributed generation** | Popular term for localized or on-site power generation. |
| **distribution line** | One or more circuits of a distribution system on the same line or poles or supporting structures' usually operating at a lower voltage relative to the transmission line. |
| **energy infrastructure** | Industries that produce and distribute electric power, oil, and natural gas. |
| **intergrid** | Converging electricity, natural gas, and telecommunications industries. |

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| **low-quality gas** | Natural gas that does not burn purely enough for market but that can be improved through technology. |
| **natural gas-to-hydrogen reforming** | A two-step process where in the first step natural gas is exposed to a high-temperature steam to produce hydrogen, carbon monoxide, and carbon dioxide. The second step is to convert the carbon monoxide with steam to produce additional hydrogen and carbon dioxide. |
| **nonrenewable fuels** | Fuels that cannot be easily made or "renewed," such as oil, natural gas, and coal. |
| **quad** | One quadrillion Btu (1,000,000,000,000,000 Btu) |
| **radiant heat** | Heat is supplied (radiated) into a room by means of heated surfaces, such as electric resistance elements, hot water (hydronic) radiators, etc. |
| **renewables** | Energy derived from resources that are regenerative or for all practical purposes cannot be depleted. Types of renewable energy resources include moving water (hydro, tidal and wave power), thermal gradients in ocean water, biomass, geothermal energy, solar energy, and wind energy. Municipal solid waste (MSW) is also considered to be a renewable energy resource. |
| **restructuring** | The process of changing the structure of the electric power industry from one of guaranteed monopoly over service territories, as established by the Public Utility Holding Company Act of 1935, to one of open competition between power suppliers for customers in any area. |
| **"Stranded" gas** | Gas supplies that are unattainable because of lack of transportation infrastructure. |

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| **Syngas** | Intermediate process gas composed of hydrogen and carbon monoxide. Used to produce a hydrocarbon liquid such as paraffin hydrocarbon liquid in the diesel fuel range. |
| **tight gas** | Gas in very low-permeability reservoirs. |
| **unconventional sources** | Resources that are contained in known strata of deposits but that require technologies different from those required to extract conventional high permeability gas reserves such as shale gas, coalbed methane, or tight gas. |

## Acronyms

| | |
|---|---|
| AEO2001 | *Annual Energy Outlook 2001* |
| AGA | American Gas Association |
| ARI | Advanced Resources International |
| ATS | Advanced Turbine Systems |
| BCHP | Buildings Cooling Heating and Power |
| bpd | barrels per day |
| CCAP | Climate Change Action Plan |
| CNES | *Comprehensive National Energy Strategy* |
| CNG | Compressed Natural Gas |
| DOA | Department of Agriculture |
| DOC | Department of Commerce |
| DOE | United States Department of Energy |
| DOI | Department of the Interior |
| EERE | Office of Energy Efficiency and Renewable Energy |
| EIA | Energy Information Administration |
| EPA | Environmental Protection Agency |
| EPAct | Energy Policy Act of 1992 |
| F-T | Fischer-Tropsch |
| FE | Office of Fossil Energy |
| FERC | Federal Energy Regulatory Commission |
| GAX | Generator Absorber Heat Exchanger |
| GNP | gross domestic product |
| GOM | Gulf of Mexico |
| GTI | Gas Technologies Institute |
| GTL | Gas-to-Liquids |
| ICHP | Industrial Combined Heat and Power |
| IOF | Industries of the Future |

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| **IT** | information technology |
| **ITM** | Ionic Transport Membrane |
| **LERDWG** | Laboratory Energy Research and Development Working Group |
| **LNG** | Liquefied Natural Gas |
| **MC** | molten carbonate |
| **MMS** | Minerals Management Service |
| **MSCFD** | million standard cubic feet per day |
| **NEMS** | National Energy Modeling System |
| **NETL** | National Energy Technology Laboratory |
| **NG** | Next Generation*Natural Gas |
| **NGT** | next generation turbine system |
| **NGV** | natural gas vehicle |
| **NPC** | National Petroleum Council |
| **NSPS** | New Source Performance Standards |
| **O&M** | operation and maintenance |
| **OPEC** | Organization of Petroleum Exporting Countries |
| **OTM** | Oxygen Transport Membrane |
| **PCAST** | President's Committee of Advisors on Science and Technology |
| **PEM** | proton-exchange membrane |
| **SCNG** | Strategic Center for Natural Gas |
| **SECA** | Solid State Energy Conservation Alliance |
| **T&D** | transmission and distribution |
| **Tcf** | trillion cubic feet |
| **UCTFI** | Ultra-Clean Transportation Fuels Initiative |
| **USGS** | U.S. Geological Survey |